ERIDOB2024

14th Conference of European Researchers in Didactics of Biology

Lyon - France, July 1st–5th

CONFERENCE BOOK

SYMPOSIUM

ROUNDTABLE

Teaching socioscientific issues and socioscientific inquiry

The Quality Education for Sustainability Teaching Framework: A QUEST for inter- and transdisciplinary biology teaching

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Theoretical background and rationale
People and organisations may yet achieve sustainability adapting their behaviour in an enabling (socio-political) context. This transition process requires education to offer students opportunities for developing action competence. We consider someone action competent when they (a) are capable of acquiring relevant knowledge and skills to find and discuss different ways for solving sustainability issues, (b) are committed and passionate about this, (c) have confidence in their capacities, and (d) have confidence in the impact of action (Authors, 2020).
ESE facilitates students' action competence development through holistic and pluralistic learning by doing (Authors, 2022; Authors, 2023; Author, 2019). Likewise, Socio-Scientific Inquiry-Based Learning (SSIBL) requires students not only to (a) ask relevant questions, and (b) find answers, but also (c) to act (Ariza et al., 2020). Both approaches underscore the importance of a biology education that looks into social justice alongside the environmental aspect of sustainability action.
In sum, ESE and SSIBL share a focus on educational arrangements that are (a) holistic, (b) pluralistic, and (c) action-oriented. The Quality Education for Sustainability Teaching (QUEST) framework includes this as the 'why' (enhancing action competence), 'what' (holistic content and integrated skills), 'how' (pluralistic and action-oriented approach), 'where' (location), and 'with whom' (partners) of the teaching-learning process.

Key objectives
Central objective of this paper is to present the QUEST framework which was operationalised as a questionnaire (QUEST-Q). We offer an overview of its components, i.e. (a) the 'why', (b) 'what', (c) 'how', (d) 'where', and (e) 'with whom' of learning-teaching processes aimed at enhancing students' action competence. The latter is defined as students' (a) knowledge and skills, (b) willingness to contribute, (c) confidence in their own capacities, and (d) in the impact of sustainability actions.
Additionally, we present the QUEST-Q, providing a measure of how students experience ESE teaching at their school. The framework may inspire teachers as they make decisions regarding biology teaching designed to enhance students' action competence.

Research design and methodology
Four steps (Furr, 2011) guided the QUEST-Q's development. Firstly, we reviewed the literature in order to articulate the QUEST framework. We then generated an initial item pool. Thirdly, a qualitative pilot provided feedback on accuracy of the questionnaire's format and phrasing. Finally, data (n = 405) collected in Sweden (n = 148), Flanders (Belgium; n = 202), and The Netherlands (n = 55) allowed examining psychometric properties and quality of the initial questionnaire (correlation and confirmatory factor analyses).

Findings
1 Articulation of the QUEST framework
A literature review yielded a framework consisting of four main components of teaching and learning. This includes educational content in terms of relevant knowledge and skills ('what'), a pluralistic and action-oriented approach ('how', i.e. inter- and transdisciplinary learning by doing), partners ('with whom'), and locations ('where'). Aim of this teaching-learning approach is to enhance students' action competence in order to equip them for facing current and future sustainability challenges ('why').
2 Development of an initial item pool
Step 1 informed generation of a 111-item questionnaire, tapping into content, approach, partners, and locations.
3 Accuracy check of items and answer scales with representatives of the population (15 to 19-year-olds) inspired a revision of the QUEST-Q.

4 Psychometric properties and quality check: piloting the resulting questionnaire (*n* = 405), showed good to excellent reliability (Cronbach's alphas between .83 and .97) of the subscales ('what', 'how', 'with whom', 'where'). Different QUEST-Q models were verified, yielding varying results (e.g. robust CFI between 0.80 and 0.92; robust TLI between 0.80 and 0.90).
The QUEST framework (step 1) provided a comprehensive foundation for the development of a measurement instrument that consists of the four main components, which were further refined. Relevant knowledge includes a focus on, inter alia, different perspectives and integrated (holistic) knowledge of various aspects of sustainability problems. Required skills refer to future, critical and systems thinking; problem-solving, and communication skills. Knowledge and skills make up the 'what' (i.e. content) of teaching and learning.
The 'how' of an ESE approach consists of teaching that enhances self-efficacy and motivation, is transdisciplinary, inquiry-based, and provides room for discussion and learning by doing (orientation towards action).
The 'what' and 'how' can occur in various locations ('where'), such as indoors/outdoors, in nature/urban settings, in and beyond school grounds, in the local/global community.
Finally, there should be collaboration between different partners, such as different subject teachers, experts, policy makers.

Conclusions
The QUEST framework can be used to shape thinking about how to provide students with support for acquiring sustainability related content holistically, approaching sustainability issues in a pluralistic way by including the views of different partners, and learning by doing in a variety of contexts and places (inter- and transdisciplinarity). The questionnaire (QUEST-Q) taps into how students experience the content, approach, locations, and partners of the teaching-learning process. It is a promising instrument and will be further validated. This comprehensive framework may inspire biology teachers when designing educational arrangements (that focus on action competence building) and selecting suitable contents, approaches, partners, and places. During the presentation at ERIDOB, we will briefly present future research plans and potential ways in which both the QUEST framework and questionnaire may inspire educational practice.

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Biology Teachers' Pedagogical Content Knowledge of Lesson Planning on Social Scientific Issues

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Theoretical background

Teaching *Socio-scientific Issues* (SSI) is challenging for biology teachers (Alfs 2012; Pohlmann 2019; Friedrichsen et al. 2021). Current empirical research indicates that teachers possess fundamental *pedagogical content knowledge* (PCK) on SSI. However, teachers struggle to apply this knowledge in everyday school situations (Pohlmann 2019). In order to support teachers in practice, it seems necessary to investigate the PCK used in action (*enacted PCK*, ePCK). The focus is on lesson planning, which is a critical stage when making fundamental decisions about teaching. Also, this process represents a significant aspect of teachers' everyday lives. To plan adequately, teachers process their domain- and situation-specific PCK in the context of SSI (Carlson et al. 2019). This knowledge base for teaching consists of interacting components (Park & Chen 2012). Little is currently known about the role of PCK in teachers' decision-making when they plan science lessons in the context of SSI (Großmann & Krüger 2022). Therefore, this study aims to characterise ePCKp within the domain of SSI (Carlson et al. 2019). There is evidence to suggest that the component *Orientations to Teaching Science* (OTS) may exert a more significant impact on these decisions (Friedrichsen et al. 2021).

Key objectives

1. Which components of their Pedagogical Content Knowledge (ePCKp) do biology teachers draw on when planning SSI lessons?
2. To what extent does the connection of enacted PCK components differ in different planning decisions in context of SSI?

Research design and methodology

To analyse the situation-specific PCK components used by German teachers during lesson planning, semi-structured individual interviews were conducted (Mey & Mruck 2010). Six tasks on SSI, derived from current German biology textbooks, were used as stimuli to maintain an interview atmosphere that mirrors everyday planning settings. The teachers' pedagogical reasoning was recorded using think-aloud methodology (Konrad 2010) The tasks included SSI topics such as abortion, genetic engineering and homosexuality. Teachers were asked to vocalize their decision-making on implementing these tasks in their everyday teaching.
The participants (n = 11) were selected through a theoretical sampling strategy which aimed at heterogeneity regarding their length of service and second subjects. The interviews lasted between 30 and 69 minutes (Mean = 48.27, SD = 10.64). The interview data were transcribed and subsequently analysed using qualitative content analysis (Kuckartz 2018). An existing category system (Großmann & Krüger 2022) was adapted and inductively extended for data analysis. PCK maps were then produced to illustrate the interconnectivity of the components. Since there is little empirical knowledge about the decision-making process in planning (Großmann & Krüger 2022), the second research question is answered by comparing PCK maps. Maps were differentiated in terms of planning decisions on whether or not to use the task in their own teaching.

Findings

The participants' reasoning relied on all components of PCK (Park & Chen 2012). PCK maps depict the interconnectedness of these components (Park & Chen 2012, see Fig. 1). The resulting PCK maps confirm the importance of the components *Knowledge of Student's Understanding in Science, Knowledge of Instructional Strategies for Teaching Science* and *Orientations to Teaching Science (OTS)* in the context of planning SSI lessons. In the component of OTS, some biology teachers showed conflicting goals for their biology classes: they wanted students to make independent decisions and at the same time had planned certain judgments that students were expected to make, or they prioritised biological knowledge over SSI. However, there are indications that teachers' decisions regarding the usage of certain textbook tasks may depend on their OTS, as these are more prevalent in PCK maps that reject the material.

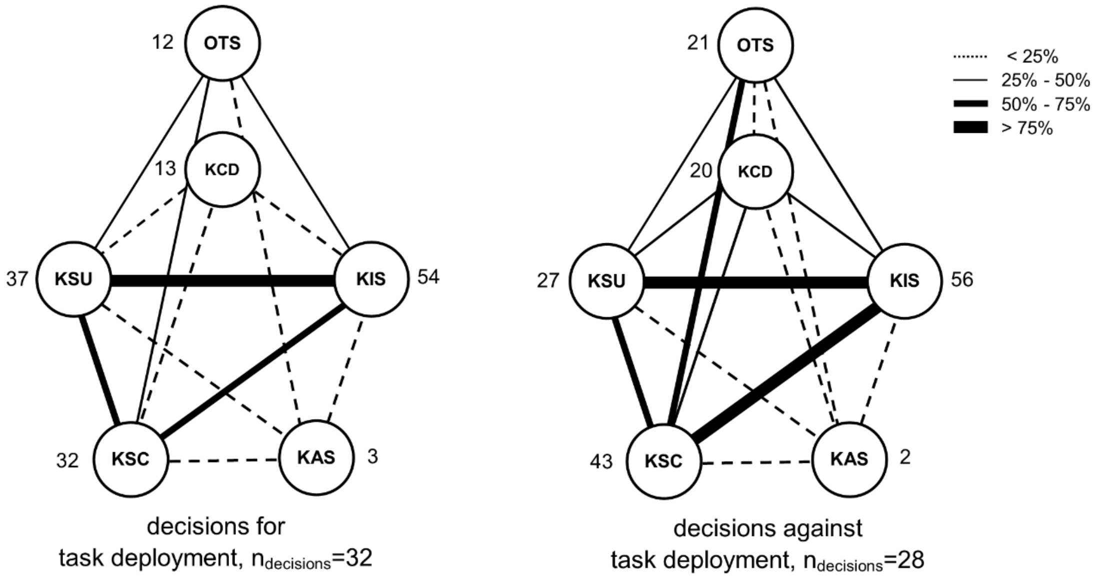

Fig. 1: Summed PCK map of decisions for (left) and against (right) the use of the socio-scientific impulse task in class. The thickness of the lines represents the frequency of the connections between the PCK components *Orientations to Teaching Science* (**OTS**), *Knowledge of Students' Understanding in Science* (**KSU**), *Knowledge of Science Curriculum* (**KSC**), *Knowledge of Instructional Strategies* (**KIS**) *Knowledge of Assessment of Science Learning* (**KAS**) and *Knowledge of Competence Development* (**KCD**).

Conclusions

In our study we found that the components *Knowledge of Student's Understanding in Science* and *Knowledge of Instructional Strategies for Teaching* influence lesson planning in the context of SSI, which is in line with former research in other contexts (Alfs 2012; Bayram-Jacobs et al. 2019; Pohlmann 2019). However, OTS seem to be even more relevant when teachers decide to employ a specific SSI task. The teachers in our study have varying and to some extent conflicting objectives OTS, such as wanting independent decisions by students and at the same time certain judgments as an outcome of the lesson. In order to support teachers in engaging their students with SSI, in particular OTS should be considered more closely on a research level (Friedrichsen et al. 2020). In addition, OTS may serve as a starting point and important resource for teacher training and professional development programs.

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How biology-teachers construct the relationship between (the nature of) scientific knowledge and sustainability issues - a reconstructive interview study

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Open schooling: Collaboration between schools and society to promote students' relevant and meaningful biology learning

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Theoretical background or rationale
Modern societies face a wide range of complex challenges, such as fighting climate change, protecting the environment, and promoting healthy living. To successfully address such challenges, citizens must actively engage in public dialogue and participate responsibly in science-informed decision making. Conventional schooling has not been able to achieve this goal: There is a wide-spread lack of scientific knowledge at all level of society and students' interest in science tends to decline within school years (Hazelkorn et al., 2015; Potvin & Hasni, 2014). This is often due to abstract and decontextualized science teaching (Christidou, 2011), negatively impacting also students' feeling of self-efficacy (Barmby et al., 2008). To address this problem and to ensure students' relevant and meaningful biology learning, we need to overcome the gap between school and real life and promote students' engagement with socio-scientific issues fostering interest, empowerment and authentic biology learning.
The European H2020 project MULTIPLIERS aims to expand science learning through open- schooling, i.e., fostering cooperation between schools and society and involving the students in real-life projects. To achieve this, the project has established novel learning partnerships ("Open Science Communities") where schools, families, research institutions, industry, informal learning providers, policy makers, and media collaborate in order to foster the students' engagement with contemporary challenges. In these learning projects ("Open School Science learning projects = OSS projects), the students work with various stakeholders to explore different perspectives and improve their understanding while gaining first-hand experiences and insights into research practices and discussions. The students then act as "multipliers", sharing their knowledge through family involvement and community events or by creating science communication media, such as podcasts and videos.

Key objectives
In our presentation, we will focus on three biology education case studies from Germany, Slovenia and Sweden where students and science experts worked together on different socio- scientific issues. Evaluation studies were conducted to identify methodological approaches and learning environments that promote relevant and meaningful biology learning.

Research design and methodology
For the evaluation of the OSS projects, we collected qualitative data from participant observations and semi-structured interviews as well as focus group discussions with the participants (i.e., students, teachers, science experts, families, and community members).
In Germany, two secondary school classes (students' age 13-14 and 16-17 years) participated in an OSS project on vaccination. They collaborated with immunobiology researchers, medical students and ethics experts, visiting different lab facilities and engaging in discussions about vaccination programs. During the multipliers phase, the students created an explanatory video and podcasts for peers and student outreach.

In Slovenia, OSS projects on biodiversity and ecosystem services included students from two primary school classes (students' age 6-11years), science experts from research institutions and NGOs, as well as media and outdoor education experts. Students utilized "natural science backpacks" containing everyday items, such as stings, spoons and knives, and technical equipment, such as binoculars and laboratory tubes. They used these backpacks at home, involving their parents in the learning processes for one week to observe and explore various living environments of their choice, and document findings in research diaries. Additional multiplying activities took place at a science fair and through science communication media production.
Swedish students (two classes, 15-17 years) collaborated with science experts from research institutions, forest industry professionals, and media on the topic of forest use vs. forest protection. Students engaged in role-play debates and critically analyzed media representations of forest issues. They also conducted interviews with individuals from three different generations about their relationships to forests, thereby

involving community members of various ages and cultural backgrounds and discussing values and individual experiences.

Findings

The data show that the engagement in scientific practices using authentic equipment triggered the students' interest. High attention and students' engagement was also observed and reported for the different debate activities. It was found that promoting the students' autonomy and leadership, while taking on the role of knowledge multipliers, fostered their interest, self- efficacy, and knowledge acquisition. Students were particularly positive about out-of-school experiences in authentic settings, opportunities to work independently in groups, and about the support of the experts. The possibility to ask personal questions about the experts' careers as well as gaining insights into their everyday (work)life was mentioned as another highlight in the student interviews.

The experts themselves stated that they value the interaction with the students as well as their critical questions, and the students' interest in the topics and in their work. They also appreciate the collaboration in the project as a good opportunity for science communication.

Our data show that flexibility in timing and a constant communication, as well as clear tasks and role distributions are necessary to enable a successful cooperation between schools, science experts and other societal stakeholders.

Conclusions

Learning partnerships where schools and societal stakeholders work together to enable the students' engagement with socio-scientific issues help to promote relevant and meaningful biology learning, fostering the student's interest and empowerment. In the MULTIPLIERS project, further OSS projects will be conducted and evaluated in order to derive final recommendations and publish guidelines and materials for successful open-schooling activities.

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Students' values, attitudes and decision making

Effects of design-oriented learning arrangements in cross-domain problems on intrinsic motivation of high school pupils

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Theoretical background
The state of research on interest promotion in science shows that hands-on activities can positively influence pupils' interest in science and technology topics (Swarat et al., 2012). However, the influence of hands-on activities depends on individual prior experience (Holstermann et al., 2010), the type of activity, and how the activities are reflected upon (Potvin and Hasni, 2014). Activities taking place in the laboratory and using digital media are most interesting to pupils (Swarat et al., 2012). Wijnia et al. (2011) also show that problem-based approaches can increase pupils' interest development, with planning processes being more significant than hands-on activities. Thus, interest-enhancing learning environments should be problem-based, include reflective, hands-on activities, and pay attention to pupils' basic psychological needs (Tsai et al., 2008). Previous research on interest development has focused primarily on hands-on science activities. So far, little research has been done on approaches at the intersection of biology and technology. One of these activities is the design of prototypes, in which technical solutions are developed on the basis of biological knowledge. Here, biology and technology overlap with regard to a. the similarities in working methods (cf. NR, 2011) and
b. in terms of content in the consideration of structural and functional relationships (Authors., 2021).

Research question:
Building on insights into the development of pupils' interests, we have developed problem- based and cross-domain learning opportunities in which pupils generate solutions via design processes for which biological phenomena serve as idea sources.
Given this background, we pose the following research question:
Q1: What is the impact of design-based cross-domain learning arrangements on the intrinsic motivation of high school pupils?

Research design and methodology:
The research question is investigated in a quasi-experimental research-design. For this purpose, 3 learning settings are contrasted: The design group, designing a product independently, the replication group replicating a product with the help of a plan, and the biology-group elaborating structure and function relationships on different biological phenomena.
Intrinsic motivation will be assessed using the Short Scale of Intrinsic Motivation (Wilde et al., 2009) once related to general Science/Biology lessons and once related to the specific intervention: Furthermore, the study will assess Subject knowledge (self-administered knowledge test), tested pre-, post- and follow-up. Data were collected in a paper-pencil format and analysed using SPSS (29.000). Longitudinal and cross-sectional analyses within groups and group comparisons were conducted.

Sample
The sample consisted of 413 pupils, distributed among 3 interventions. The biology-group consisted of 134 pupils (67 boys, 67 girls) aged M= 12.6 SD= 0.7 . In the design group, 148
pupils (78 boys, 70 girls) aged M= 12.35, SD= 0.91, participated. 131 pupils (62 boys, 69 girls, age M=12.60 SD = 0.74)) underwent the instructional sequence "replication"

Findings:
Based on the mean scores of the motivation scale, all approaches show means of motivation above average (M > 2.00). Investigations of gender differences show non-significant for all intervention groups (organic: U=1919, p = .147; design U= 2638 ,p= .724 post-design: U= 1722 p = .054). In addition, all intervention groups show a statistical increase in motivation compared to standard instruction (Table1)

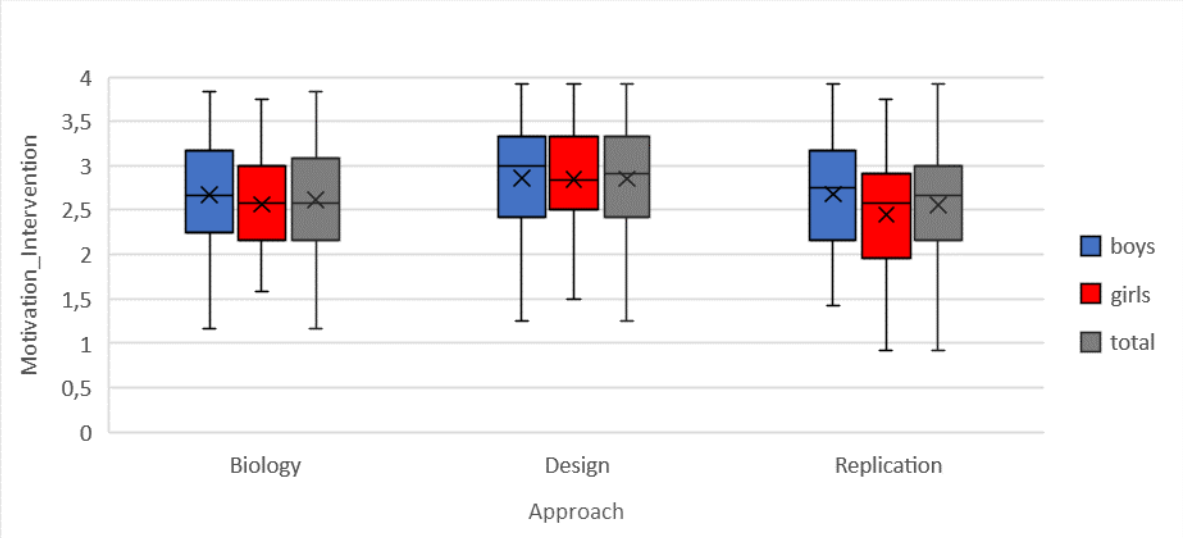
Table 1: Wilcoxon Test: Comparison of Standard Instruction and Intervention

	Z	p	r
biology	-4,246	p < .001	.367
design	-4,650	p < .001	.388

replication	-3,457	p < .001	.389

In group comparison (single ANOVA) (Fig.1) the intervention groups show significant differences related to intrinsic motivation: $F(2, 410) = 9.849$, $p < .001$, $\eta^2 = .046$. The Tukey- post- hoc test shows significantly higher motivation scores in the design group compared to both other groups (Bio.: p = .003, replication.: p < .001).

Figure 1: Comparison between the intervention groups



Separated by gender, boys show an insignificant picture $F_{boys}(2,204) = 2.255$, $p=.107$ $\eta^2 = .022$. Tukey post-hoc test shows no significant differences between design group and the other groups (Bio.: p=.152, replication p = .182). In contrast, significant differences are shown for girls $F_{girls}(2,203)= 8.673$ $p < .001$, $\eta^2 = .079$, post-hoc test shows significant difference between intervention groups (Bio: p = .013, replication p < .001).

Conclusions:
All of the intervention groups have a strong hands-on component. In this respect, all approaches also show a motivational effect that affects both genders equally. However, the group comparisons show that design-related tasks generate significantly higher motivation values and appeal especially to girls. Considering the gender-specific interest gap in the STEM professions, this suggests that design-oriented cross-domain learning opportunities could be a methodology that could be used for the specific promotion of girls.

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Nature encounters on schoolgrounds. A reconstructive study with primary school pupils

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Theoretical background

The fundamental premise of this research is that people have diverse accesses to nature. This premise is grounded in the theoretical framework proposed by Gebhard (2020), which suggests that individuals can engage with nature in both subjective and objective ways. Furthermore, different facets of encounters with nature give rise to distinct approaches. Building upon Lude's work (2021), we distinguish between three types of encounters with nature: those involving passive engagement, those centered on sensory and active interaction with the natural world, and those that involve reflective experiences. In the German language, these are distinguished by the terms 'Erlebnis' and 'Erfahrung'. Additionally, the subjective approach encompasses the dimension of symbolic experiences of nature, where what is both experienced and contemplated relates to the self and can become a profound and meaningful experience (Gebhard, 2020). All these approaches and dimensions hold significance for child development (Chawla, 2020; Raith & Lude, 2014). For instance, Dyment (2005) and Raith (2016) have demonstrated that green spaces on school grounds can facilitate various forms of encounters with nature.

Key objectives:

The objective of this study is to explore the various dimensions of nature encounters facilitated by differently designed (near-natural) school grounds. A critical aspect of this investigation lies in understanding how primary school students select their preferred locations on the school grounds and what they are guided by. This led to the following research questions:

1) What do primary school pupils orient themselves to (according to Bohnsack (2017)) in their encounters with nature on the school grounds?
2) How do primary school pupils encounter nature on the school grounds?
3) What didactic and design consequences can be derived from the explicit and implicit knowledge of primary school pupils for the design of school grounds and breaks?

Research design and methodology:

In the research project presented here, a total of 17 pupils at three primary schools were interviewed about the places they spend time and the nature encounters they have during recess. The school grounds differ in their external design, their closeness to nature and their pedagogical framing. This resulted in three groups of primary school pupils: a group from a near-natural school site (n=10), a group from a far-natural school site (n=9) and a group from a non-natural school site (n=8). The interviews were conducted using the go-along method, as described by Kusenbach (2003), wherein the interviews took place while walking in the area of interest, allowing the environment to become an integral part of the conversation. Subsequently, the interviews were analyzed utilizing the documentary method by Nohl (2017).

Findings:

The reconstructive interpretation of the interviews showed that the students are influenced by various aspects in their choice of location. Institutionalised norms, such as how one has to behave as a pupil on the school grounds or that some areas belong to certain classes, as well as role expectations, which e.g. the break helper service or gender entails, influence where they stay. Play and recess rules, e.g. concerning the use of nature (e.g. "you are not allowed to climb trees"), also limit the possibilities for encountering nature.

Concerning to Bohnsack (2017), these norms are in tension with the habitus of the pupils (Bohnsack, 2017). As an integral aspect of the shared habitus among all primary school pupils, an orientation towards their needs could be reconstructed. After the norms, rules and expectations have provided certain framework conditions, the primary school pupils orient themselves within this framework to their needs during the break and then choose a suitable place. These needs were very similar on all three school grounds, no matter how close to nature they were. However, when nature is present on the school grounds and in the areas where they spend time, nature is also included in their play and need satisfaction.

It is unsurprising that only on the far-natural and near-natural school grounds, both nature experiences with or without reflection take place. On the non-natural school ground the pupils only made nature encounters.

Nature encounters mainly take place while playing football, playing catch and moving around. Using one's senses actively (as part of nature experiences) happens when observing animals, building or climbing. But also, negative nature experiences such as getting dirty or wet are part of the nature encounters. Nature experiences are reflected when nature spaces are utilized as retreats, for relaxation after school, or for exploring wildlife and crawling through bushes.

Conclusions:

The collective findings of reconstructing the childrens' orientations and the normative framework provide valuable insights into various didactic and spatial design recommendations for nature-oriented school grounds, which will be presented at the conference. For example, that more needs can be met by separating areas for movement and for rest. Or that spaces should have a potential for own design in order to be able to experience nature and reflect on it.

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Expanding and Enhancing the Notion of Photosynthesis Education in an Educational Design Research Study

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Rationale

Photosynthesis, without doubt, are an important process on earth. Students are supposed to learn about the process and why it is important. All over the world, photosynthesis is incorporated in biology curricula. However, the learning about photosynthesis is not successful in order to educate scientific literate students (Simmie et al., 2021). The concepts in today´s photosynthesis education is experienced as abstract by students (Espinoza et al., 2022). For example, energy conversions and invisible processes at the molecular level are difficult to concretize. When such abstractions are presented for students many of them have already an own rudimentary idea about how plants work. Consequently, if the photosynthesis instruction in school is not clear enough the students might develop misconceptions. Misconceptions about photosynthesis are common all over the world, even among teachers (Simmie et al., 2021). If such misconceptions remain, students will lack the understanding of the photosynthesis that scientific literate citizens need for dealing with sustainability issues. Such link to sustainability is not fully addressed in today's photosynthesis education. Research on teaching practice shows that the teaching in photosynthesis usually is carried out in a mechanistic way and are learned by rote. This teaching is according to Mekonen and Kelkay (2023) done as lecturing in a "chalk and talk" method of teaching. Therefore, students have a risk to miss possibilities between photosynthesis and the solving of sustainability issues. For example better utilization of photosynthesis, harvests can be increased and humanity can have easier access to food (da Fonseca-Pereira et al., 2022).

Key objectives

Sustainability issues and photosynthesis have connections. Photosynthesis processes are important to consider when dealing with many sustainability issues (Matthews, 2009). Four of the goals of Agenda 2030 involves photosynthesis processes: No hunger (Goal 2), sustainable energy for all (Goal 7), combatting global warming (Goal 13) and protecting biodiversity (Goal 15). A key objective in this study is therefore to develop a photosynthesis teaching design within biology education that more closely connects the photosynthesis with sustainability issues. By making students see these connections in local settings, it is hypothesized that the students will 1) develop a deeper understanding of the importance of photosynthesis for sustainability and 2) will be more motivated to take sustainable actions.

Research design and methodology

Education research design (EDR) is the methodology basis in this study. EDR implies a naturalistic approach with collaboration between researchers and teachers trying to improve a set of lessons in a tentative way (Van den Akker et al., 2006). The setting in this study is a lower secondary school in rural part of Sweden. Collaboration is done between a researcher and two biology teachers. As a baseline for the study a Delphi-study was conducted to identify relevant learning goals and content themes for this broadened teaching approach of photosynthesis connected to sustainability (Authors, in preparation). The outcome of this Delphi-study was used as design principles for the EDR project. First, the results from the Delphi-study were discussed with the teachers and transformed into a teaching design. Thereafter in three rounds of the EDR-process we, in a tentative way, tried to improve the teaching design (a set of ten lessons) concerning photosynthesis and its connections to sustainability. We are now in the last third round of lessons. Pretest and posttest are conducted in every round of the EDR. Together with interviews of students and teachers, video recordings and notes taken by the researcher, we develop the teaching design according to the research based EDR-process in three rounds.

Findings

The preliminary findings show the importance of putting photosynthesis into the context of ecology and society to better develop students' literacy relating to this issue and create greater interest to learn about photosynthesis. This broadening of the photosynthesis education makes students more motivated to understand and learn about photosynthesis. Argumentation exercises and inquiry-based investigations in the lessons, together with outdoor excursions have triggered students' motivation. Moreover, to diminish the problems concerning the experienced abstractness of the photosynthesis process the results also highlights the importance of teaching to include aspects of concretization, with hands on experiences, such as excursions, cultivation of plants and performing laboratories. Lessons were developed in the study to facilitate learning and avoid misconceptions. At the ERIDOB-conference we will be able to present data more in detail along with the developed teaching design as well as the evaluation of it.

Conclusions

Traditional teaching of the photosynthesis in biology education leads to poor learning and the emergence of misconceptions (Simmie et al., 2021). To be motivated and learn the importance of the photosynthesis from a broader sustainability perspective, this study shows that the ecological as well as the societal context is crucial to connect to the photosynthesis process. Inquiry pedagogy and concretizations are also essential for student's deeper learning and motivation. Based on the findings of this study we would therefore recommend a reorientation of photosynthesis education towards a broader scientific literacy perspective, of which the developed teaching design could function as a facilitator for that to happen.

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Students' Conceptions and Conceptual Reconstruction

The use of bees as a non-prototypical organism in preschool: evolution of pupils' ideas about the living being model

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The living being model is one of the core scientific ideas that learners should address in preschool. They should understand what a living being is, and how it interacts with its surroundings (Shepardson, 2010). However, most proposals do not extend beyond projects centred on large animals, predominantly mammals (Gálvez et al., 2021). This limited view of living beings affects students' understanding of this model (Eckert et al., 2021). There is a need to enrich children's experiences with the study of non-prototypical living beings, e.g., insects (Barrow, 2002). They are valid teaching resources because of their diversity. Besides, educational experiences with them have a positive impact on students' attitudes towards preserving the environment (Shepardson, 2010).

Last years, their numbers have drastically decreased, which is causing problems in crop production and plant biodiversity (Ollerton et al., 2011). Therefore, it is important to work on this reality. For this reason, in this proposal, bees are chosen to address students' ideas about living beings.

In the literature on learning the living being model using insects, most papers have focused on Primary and Secondary school levels (Barrow, 2002; Eckert et al, 2021; Shepardson, 2010) and fewer in Preschool. Hence, we present a teaching sequence about the role of bees in our environment which is designed for the third year of Early Childhood Education. This work seeks to identify the evolution of pupils' ideas regarding the anatomical structures of a bee and their functions, the terms, and symbols they use to represent them, and the elements of the environment they relate with bees.

Methodology

Framed in qualitative methods, qualitative content analysis was carried out, because it allows to analyse a large data set and identify patterns among them (Schreier, 2012).

Context and participants

The participants were 10 pupils (6 boys and 4 girls) from an urban state school class (5-6 years).

The teaching sequence was designed by the authors and discussed with the teacher. It was divided into 12 sessions and lasted two months (Table 1).

Data collection and analysis

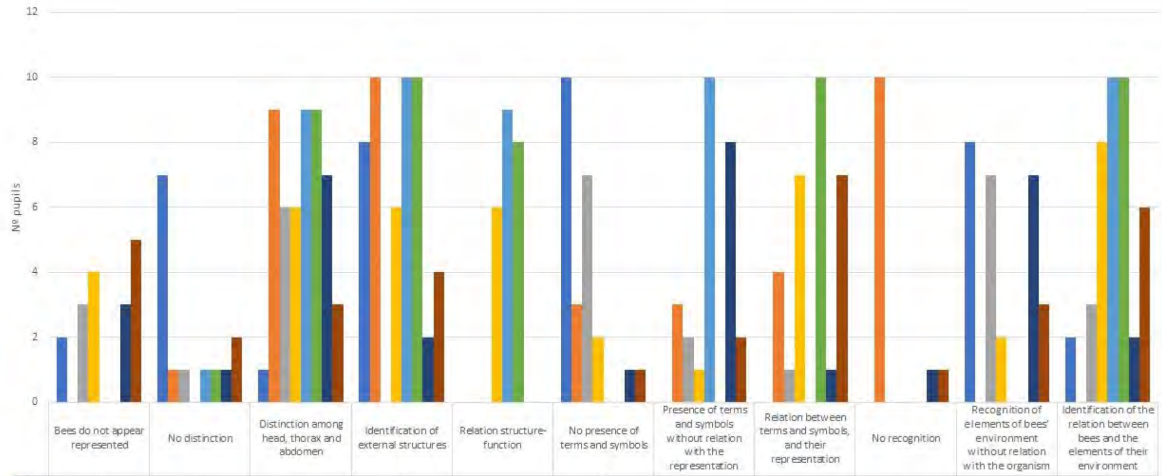
80 drawings were collected from the first and second sessions, and at the beginning and end of the fifth, sixth and ninth sessions. Drawings were used as data collection instrument because of their usefulness to analyse students' ideas. For the analysis, three categories were considered (Shepardson, 2010): the anatomical structure represented and its location; the terms and symbols used by the participants; and the elements of the environment they connect with bees. After analysing the drawings, these categories were divided into different subcategories (Figure 1).

Table 1. Summary of the teaching sequence.

	Session	Living being' ideas
1	Identification of students' initial ideas	-Anatomical characteristics of the bee as arthropod. -Bees and their interaction with their environment
2	How are the bees: anatomy and structure of the bees	-Differentiation among head, thorax, and abdomen -Morphology and function of the external parts of a bee
3	Morphology of a done, a queen and a worker bee, social characteristics, and hierarchy	-Anatomical differences among dones, queens and worker bees -Social structure of the bees and their role in the beehive
4	Life cycle of a bee	-Life Cycle of the bee -The drones' role in flight bridal -The role of royal jelly in feeding bees' larvae.
5	How do bees see?	-Characteristics of bees' vision -Relationship between bees and their environment through sight -Similarities and differences in vision between humans and bees
6	How do bees communicate?	-Bees' communication systems: Dance of the eight and the circle
7	How and where do bees live?	-Parts and shapes of a beehive
8	Connection with an entomologist!	-The excretory and digestive system of bees -The anatomical changes from bee egg to adult bee - The defensive systems of bees and their adaptation to the environment
9	Beekeeping and their environmental impact	-Bees as food producers: how bees elaborate honey - Honey's characteristics and products made with honey
10	Honey breakfast!	- The types of honey depending on the vegetation surrounding bees
11	The environmental importance of bees	-The importance of pollination process to the environment
12	Closing of the Project: MTV5years: Special bees!	-Review of previous concepts

Results

As the results show, the pupils evolved in their ideas about the structure of a bee, distinguishing between head, thorax, and abdomen and identifying elements such as the compound eyes. They also related the structures with their function, e.g., the compound eyes with their role in vision. Finally, they also recognised how bees extract pollen from flowers and produce honey (Figure 1). To exemplify the analysis, we describe the evolution of pupil A' ideas (A) based on her drawings (Figure 2).



	Bees do not appear represented	No distinction	Distinction among head, thorax and abdomen	Identification of external structures	Relation structure-function	No presence of terms and symbols	Presence of terms and symbols without relation with the representation	Relation between terms and symbols, and their representation	No recognition	Recognition of elements of bees' environment without relation with the organism	Identification of the relation between bees and the elements of their environment
S1	2	7	1	8		10				8	2
S2P		1	9	10		3	3	4	10		
S5i	3	1	6			7	2	1		7	3
S5f	4		6	6	6	2	1	7		2	8
S6i		1	9	10	9		10				10
S6f		1	9	10	8			10			10
S9i	3	1	7	2		1	8	1	1	7	2
S9f	5	2	3	4		1	2	7	1	3	6

Figure 1. Summary of results of pupils' ideas about bees.

In session 1, most of the pupils depicted bees with human characteristics or only the beehive. Others, such as A, represented the environment surrounding the bees, identifying a beehive and a plant, but without connection to the organism. In session 2, they identified external structures and represented bees' segmentation, connecting them with their terms, such as A. In session 5, they worked on bees' vision. Clear differences were identified between the initial and final drawings. Thus, in the first ones, some pupils, such as A, represented the proportion between the bee and the flower, but did not adequately illustrate bees' vision. In the final drawings, they related the structure to its function, representing the mosaic vision characteristic of compound eyes and correctly identifying the colours.

Figure 2. Example of pupil A's ideas along the sequence.

In session 6, the class studied how bees communicate. First, pupils represented at least two bees, considering, for instance, that they talked like humans. Others, such as A, represented them producing sounds to communicate and locate flowers. Then, they incorporated the idea that bees use specific strategies, such as the “figure-eight dance”, to communicate, linking performance to function. In session 9, they should represent bees’ role in producing honey. Pupils, such as A, depicted her mother going to the supermarket to buy honey. At the end, they illustrated the hexagons of the honeycomb cells and depicted a beekeeper extracting honey, connecting bees with their role in honey production.

Conclusion

As the results show, the participants developed a more complex model of living being. Meanwhile, at the beginning, they were incapable of recognizing the parts of a bee and its external structures, at the end, they managed to associate the different parts, their structures, and functions. Besides, they had come to represent bees’ role in honey production. Therefore, this teaching sequence allows pupils to establish structure-function-environment relationships to explain what a living being is; however, the concept of ecosystems and biodiversity loss was not addressed. It is essential to continue deepening in the design and implementation of similar materials at other educational stages. Line in which we are currently working on (Sevilla-Izquierdo et al., 2023).

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Students' conceptions on sugar production: A comparative and collaborative study between french west indies and Canada*

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Theoretical background:
Situated conceptions, as defined by Clément (2003), refer to the idea that learners' expressed conceptions are neither consistent nor uniform. Drawing on a classic example from the realm of biology education, namely the anatomy of the digestive system, the author illustrates that students' expressed conceptions often arise from situation-specific interpretations and may contradict their knowledge within a matter of minutes. The concept of "situated conceptions" was further expanded upon in its interactions with students' conceptions and social representations and its application within the framework of collaborative educational games (Delomier, 2013). The digital transformation has given individuals the opportunity to strengthen the social and collaborative aspects of their learning, enabling them to establish relationships and interact online (Baker & Détienne, 2019).

The contextuality of biology concepts is particularly significant, especially in the context of knowledge related to biodiversity and the environment. Authentic approaches and context- based approaches have demonstrated the importance of considering environmental contexts in science education, particularly for engaging students in their learning. The term "didactic contextualization" was specifically introduced in the context of field investigations (Giamellaro, 2014).

Key objectives:
The objective of this study is to highlight that, similar to students' engagement, their "situated conceptions" are strongly linked to their everyday life and learning contexts. More specifically, in this work, we describe and discuss learners' conceptions on the subject of sugar production. Additionally, we will study whether, in the context of collaborative interactions among students from different socio-cultural backgrounds, these conceptions undergo transformation and enrichment, shaped by the contextual dynamics in play.

Research design and methodology:
The presented results stem from the "*Anonyme*" project (funding by the ANR-FRQSC program) which aims to implement and evaluate a pedagogical innovation rooted in remote contextual comparisons across various scientific study topics, involving students from Guadeloupe and Quebec. Over several months, students engage in collaborative research on a shared scientific subject, utilizing both synchronous and asynchronous methods to present and exchange their findings. Data are collected through recordings of their interactions and the administration of pre- and post-questionnaires.

In this study, we focus on one question from a *Anonyme* experimentation about sugar production. We asked primary students to draw the sugar-producing plant, expecting Guadeloupe students to choose sugarcane and Canadian students to select maple trees. After collecting their drawings, we categorized the students' conceptions of sugar production *aposteriori* by examining the context they chose for graphical representation and considering other observed elements in their drawings.

Findings:
The following section relies on the analysis of 94 drawings obtained from both the pre- and post-questionnaire phases. These are drawings for which we could interpret the content without any ambiguity.

<u>Finding 1: Contextual conceptions</u>
As expected, the majority of the respondents represent the plant from their respective contexts (sugarcane in Guadeloupe, maple tree in Quebec). As shown in the Table 1, in post- questionnaire phase some students (3 in Guadeloupe, 12 in Quebec) chose to represent both plants as examples of vegetation which produces sugar.

Table 1 : Summary of the selected drawings for analysis

	Drawings kept for analysis	N drawings of sugarcanes	N drawings of maple tree
Pre-test (Guadeloupe)	21	21	0
Post-test (Guadeloupe)	23	23	3
Pre-test (Quebec)	25	4	25
Post-test (Quebec)	25	12	24
N in total	**94**	**60**	**52**

By closely examining the drawings, we identify elements related to plant biology and agricultural aspects, such as cultivation tools, sugar collection, and field workers. Consequently, here are two more findings.

Finding 2: The overrepresentations of sugarcane stalks and maple tree trunks

As illustrated in Figure 1, a significant number of students prioritize represent graphically the fibrous stems of the sugarcane plant and the central trunks of maple trees in their drawings. We believe that reducing drawings primarily to the storage organ in sugar plants responsible for sugar production or the harvesting site can be viewed either as an utilitarian approach to illustrating plants or as an intention to provide an explanatory diagram showcasing the utility of these plants.

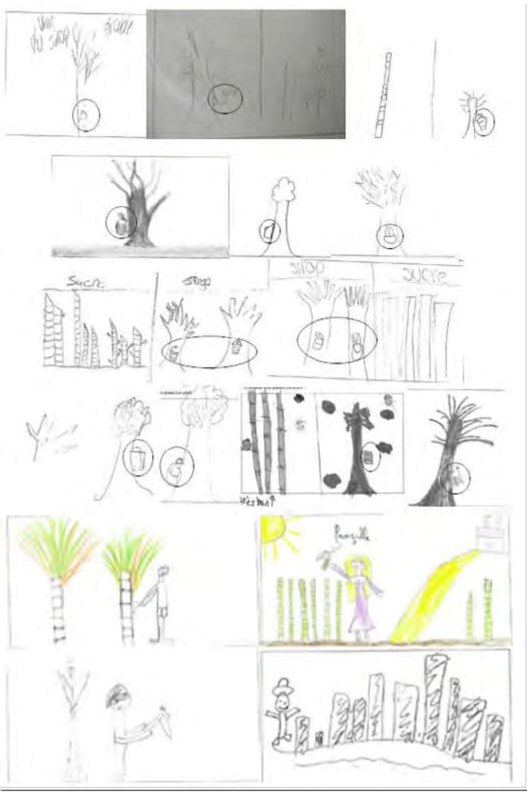
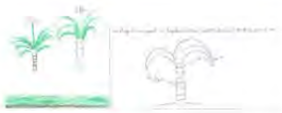
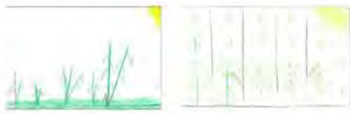


Figure 1 : Examples of reductive drawings collected

Finding 3: Multiple representations of sugarcane plants and prototypical leaves

The following table (Table 2) shows the various categories identified when students in Guadeloupe chose to represent their local plant, the sugarcane.

Table 2 : The sugarcane leaf representation as drawn by learners in Guadeloupe

	Representations	Examples	N in pre-tests (Guadeloupe)	N in post-tests (Guadeloupe
A. Leaf shape	Rounds		3	2
	Serrated		17	20
B. Leaf extension	Extending		13	19
	In the middle		5	3
	Both		2	2

Most students in Guadeloupe drew sugarcane leaves that looked like coconut tree leaves, with serrated edges or extending from the sugarcane stalks. A notable finding from the data is that some students from Guadeloupe drew sugarcane plants with round leaves, as if they represented a basic leaf concept.

Conclusions:
In the pre-test phase, students primarily represented the plant from their own context. However, in the post-test phase, a significant number of them also illustrated the plant responsible for sugar production from the other context.

It seems that after the implementation of this collaborative experience organized within the framework of *Anonyme* project, these multiple conceptions, presented in this article, appear to be more diverse and receptive to the biodiversity of various environments. They are not only "situated" but also deeply contextual in several ways, as they represent a plant in one context, another, or even in both contexts. These conceptions are influenced by the situation (situated conception) and are profoundly connected to the students' cultural and biological context. It is in this sense that we propose the term "contextual conception."

Finally, we are aware of two limitations in our research. The first limitation is that our study primarily focuses on qualitative aspects and is not designed to represent a larger population beyond the students in this specific project. The second limitation is related to categorization based on context, as it can be challenging to apply identical categories to drawings created by learners from different contexts. For example, in our case, it would not be suitable to use the exact same categories for drawings depicting sugarcane and a maple tree. The second is that when categorizing based on context, it can be challenging to use exactly the same categories for items drawn by learners from different contexts.

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Fostering conceptual transformation on plant nutrition – the progression of concepts and notions in a digital collaborative learning environment

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Theoretical background or rationale

Within the domain of science education, it is established that grappling with the significant challenges of our time necessitates more than a mere accumulation of factual knowledge. It demands an understanding of the "big picture" (Fischer et al., 2002). In this context, the process of "learning" is a change of conception rather than the acquisition of isolated facts. The Conceptual Metaphor Theory (Lakoff & Johnson, 2003) not only elucidates the genesis of these conceptions but also provides a comprehensive understanding of their nature.

Analysing learners' drawings and the verbal structures they employ is instrumental in identifying existing conceptions on plant nutrition. Any change in learners' conceptions should encompass specific characteristic in line with the Conceptual Change Theory (Strike & Posner, 1992), wherein learners manifest dissatisfaction with existing conceptions, adopt an alternative conception that is coherent and plausible, and demonstrates the ability to effectively explain a phenomenon. The recently developed Peer-Interaction-Method (PIM) – a collaborative three-step digital learning environment – was initially designed to work with students' conceptions in the field of chemistry education (Heeg et al., 2020).

Key objectives:

Our research questions are therefore: What kind of conceptual changes take place through the use of PIM on the topic of plant nutrition? What are the causes of these changes and possible implications for learning environments in biology lessons?

Research design and methodology:

Addressing these inquiries a qualitative study involving 8 participants, comprising philosophy students aged 20-24 from diverse disciplines (6 female, 2 male) was conducted. The Peer- Interaction-Method (PIM) is based on the "Think-Pair-Share" approach: Employing the PIM, learners engaged in a drawing task on the topic of plant nutrition (phase 1), followed by collaboration with a fellow participant to jointly resolve the same task (phase 2). Leveraging the drawings (Author, 2022) produced in phase 1, participants with noticeable differences (Author, 2018) in conceptions were grouped in two in order to create heterogeneity. In phase 2 participants explained their individual solutions from phase 1 and engaged in a negotiation process to develop a jointly supported solution. In phase 3, guided interviews were conducted to elucidate the jointly formulated solution and reflect on the negotiation process. The drawings were created using tablet computers and a digital PIM plug-in. Video recordings captured the negotiation process in phase 2, while audio recordings were made during the interviews in phase 3 for later analysis. Employing qualitative content analysis (based on Mayring, 2004) aligned with cognitive linguistics (Johnson, 2005), the drawings and the language used were scrutinized. In order to measure learning progress, the identified conceptions were evaluated based on their alignment with scientific conceptions. Inter-rater reliability was confirmed through rating verification.

Findings:

Categorizing learners' expressions into three pertinent notions relating to plant nutrition, the outcomes depicted progression trends across groups, as exemplified in Figure 1.

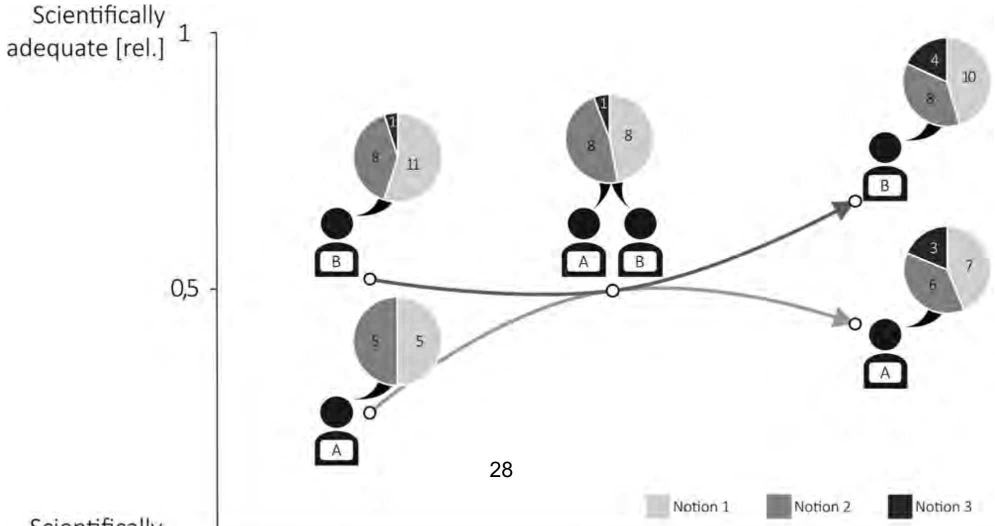

Figure 1. The conformity of scientific conceptions to the conceptions expressed by the participants. The pie charts show the absolute numbers of expressed conceptions referring to the corresponding notions (light grey: “Nutrition through substance uptake and release.”, middle grey: “Nutrition through the production of organic compounds.”, dark grey: “Gas exchange as quid pro quo principle.”).

Conclusions:

Each participant showed progress over the course of the PIM. During the negotiation process in phase 2, it was not only the case that previously made expressions no longer occurred or new expressions were adopted from the group partner. It also happened that conceptions were articulated that had not been expressed by either of the group members before. When asked to express their overall impression of the negotiation process, their answers suggest that the differences in conception within their group were not perceived. Only after they were made aware of this through a comparison of the individual work and the partner work or conversation excerpts of the negotiation process, they were willing to acknowledge differences. In some cases, the participants adopted expressions during phase 2 without any content related reasoning, but were able to make a content-related argument for their new conception in phase 3. In cases like this, participants considered content related differences to be a “threat to harmony”. These situations were always resolved through strategies on a social level. This suggests that participants pursued both, content related and relational goals.

Furthermore, efforts to maintain, establish or rebuild “harmony” seem to have a substantial impact on changes of conceptions. This study shows that besides a content related conflict, another conflict on a social level shapes the process of learning using the PIM and should therefore be considered for future developments of collaborative learning environments. This can create new perspectives on working with student’s conceptions at school as well as in research settings.

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Students Conceptions of Natural Products and of the role of school for its consumption

Zélia Anastácio

Professionalizing future biology teachers

A single session intervention increases undergraduate confidence in small group, whole class, and one-on-one discussions in active learning university biology courses in the United States

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THEORETICAL BACKGROUND

Compared to traditional lecture courses, university students learn more and fail less in active learning biology courses where they engage in their learning through activities and discussions in class (Freeman et al., 2014). However, fear of negative evaluation (FNE) prevents students from fully engaging in active learning activities (Downing et al., 2020). Fear of negative evaluation is defined as the sense of dread associated with being unfavorably evaluated in a social situation (Weeks et al., 2005) and is prominent in active learning courses because of the increased social interactions among students. FNE can cause students to struggle thinking through biology questions, struggle articulating their thoughts about biology, and avoid participating in social active learning activities (Downing et al., 2020). The solution to lessening FNE among undergraduates is not to eliminate active learning; overwhelming evidence suggests that reverting to traditional lecture would be detrimental to student learning and less equitable (Freeman et al., 2014). Instead, researchers have suggested 1) adjusting how active learning practices are implemented and 2) lessening students' FNE by bolstering confidence during academic social interactions (Yannier et al., 2021). To address the latter approach, a collaboration of clinical psychologists and biology education researchers developed and tested an online single-session intervention to bolster confidence among undergraduates in active learning biology courses.

Single session interventions (SSIs) pose a promising approach to promoting confidence among undergraduates. SSIs are defined as specific, structured psychosocial intervention programs that intentionally involve just one encounter or engagement with a program or intervention (Schleider et al., 2020) and provide an accessible, effective, and scalable way to deliver information to students. In clinical psychology, evidence suggests brief SSIs (< 30 minutes) that are online and self-guided have shown particular promise in improving emotional functioning (Schleider et al., 2021). Given the effectiveness and ease at which SSIs can be delivered to students, SSIs have the potential to provide a scalable, cost-effective means of bolstering student confidence contributing to class discussions in biology.

KEY OBJECTIVES

We developed a brief online single-session intervention (SSI) to reduce students' FNE and bolster student confidence in active learning college biology courses. During the SSI, students learn about the neuroscience-based explanations of FNE and coping mechanisms. Then, hear personal stories from peers about their experiences with FNE and write their own narratives about the coping strategies they have learned in the SSI. Our overarching research question was: To what extent does the SSI promote confidence engaging in small group discussions, in whole class discussions, and one-on-one with the instructor in active learning college biology courses?

RESEARCH DESIGN AND METHODOLOGY

We conducted a set of randomized controlled trials to answer our research questions. In fall 2022, we piloted the FNE SSI in an upper-level biology course at an R1 institution (n = 298). As a homework assignment completed outside of class, students in this course participated in a pre- survey, were randomly assigned to participate in the FNE SSI or a placebo intervention about campus mental health resources and completed an immediate post-survey. In spring 2023, we tested the SSI in introductory biology courses at the same institution. Students (n = 890) completed a pre-survey, were randomly assigned to participate in the SSI or placebo intervention and completed an immediate post-survey. At the end of the following week and at week 10 students completed a follow-up survey assessing the same outcomes. All scales included on the survey had been previously assessed to be reliable and valid for this student population.

ANALYSES AND INTERPRETATIONS:

In the pilot study of upper-level students, the intervention received a high acceptability rating (1.22 on a scale from -2 to 2) and had a high completion rate (>97%). Those who were assigned the SSI showed significant gains in confidence engaging in small-group discussions ($p < .001$), whole class discussions ($p < .001$), and one-on-one interactions with instructors ($p < .05$) from baseline to immediate post-intervention, compared to their peers who completed the placebo intervention. These findings were replicated across introductory biology courses; compared to students in the control, students who completed the SSI showed significant gains in confidence engaging in small-group discussions ($p < .001$), whole class discussions ($p < .001$), and one-on- one interactions with instructors ($p < .001$) from baseline to immediate post-intervention and the significant gains in small group ($p < .001$) and whole class discussions ($p < .001$) were retained at the one week follow up. However, the significant gains were no longer present at the 10-week follow up.

CONCLUSIONS

A team of clinical psychologists and biology education researchers developed a brief online single-session intervention, which bolstered university biology students' confidence contributing to small group and whole class discussions and the effect lasted for at least one week.

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THE IMPACT OF TEACHER RESEARCH ON PRE-SERVICE BIOLOGY TEACHERS AND THEIR FUTURE PROFESSION

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Theoretical background

Teacher research as a form of professional development has gained more and more body over the last decades (Cochran-Smith & Lytle, 2009; Davis, 2018). Teachers are expected to obtain an academic orientation -or inquiry-based stance- toward their profession by, e.g., systematically reflect upon their practice, using research outcomes in their practice and by conducting research themselves in order to evaluate and improve their classroom practices. In many countries, these expectations have guided initiatives to develop such an academic attitude already in teacher education (TE) programs. In Dutch academic TE institutes, pre-service biology teachers (PSBT) are required to conduct a design-based research project in which they explore a problem that arises from their teaching practice (e.g., how to make fieldwork effective and fun?) after which they design and test an intervention in their classroom practice (e.g., going on a field trip using gamification and digital tools). Such student research projects generally contain six phases of design-based research: A. Literature review; B. Problem analysis and research question; C. Educational design; D. Data gathering; E. Data analysis; F. Display results, drawing a conclusion and write a discussion. The main purpose of doing a research project is to develop both research skills and an inquisitive attitude, which will teachers to become adaptive, self-responsible professionals who are able to systematically improve their teaching practice using data and research outcomes, and to critically reflect on developments and reforms (Cochran-Smith & Lytle, 2009).Literature, however, shows several issues, one of which is that teachers educated in academic TE often have difficulties connecting their academic attitude properly to their own teaching practice, i.e., in a way that fits the ecology of their classrooms and the way they make day-to-day decisions in complex classrooms (Westbroek et al., 2022; Zeichner, 2003). Yet, academic teachers are expected to take a leading role in conducting and using research in schools (Westbroek & Kaal, 2016). To prepare teachers for such a leading role, we need to understand how pre-service teachers value doing research in teacher education in relation to their future profession as teachers.

In this research project, therefore, we aim to deeper understand how conducting (design-based) research contributes to the future profession of PSBT and how TE institutes can tailor their course design to contribute to these goals. It is important to understand what goals PSBT think they achieve by doing research during TE and how performing the six successive research phases of design-based research contribute to the goals that teachers have in view of their future profession. The two research questions:

RQ 1: What are the goals that pre-service Biology teachers want to achieve for their future profession?

RQ 2: How does each individual phase of design-based research contribute to the attainment of these goals?

Key objectives

To deeper understand how conducting didactical research contributes to the future profession of pre-service biology teachers (PSBT) and how TE institutes can tailor their course design to contribute to these goals.

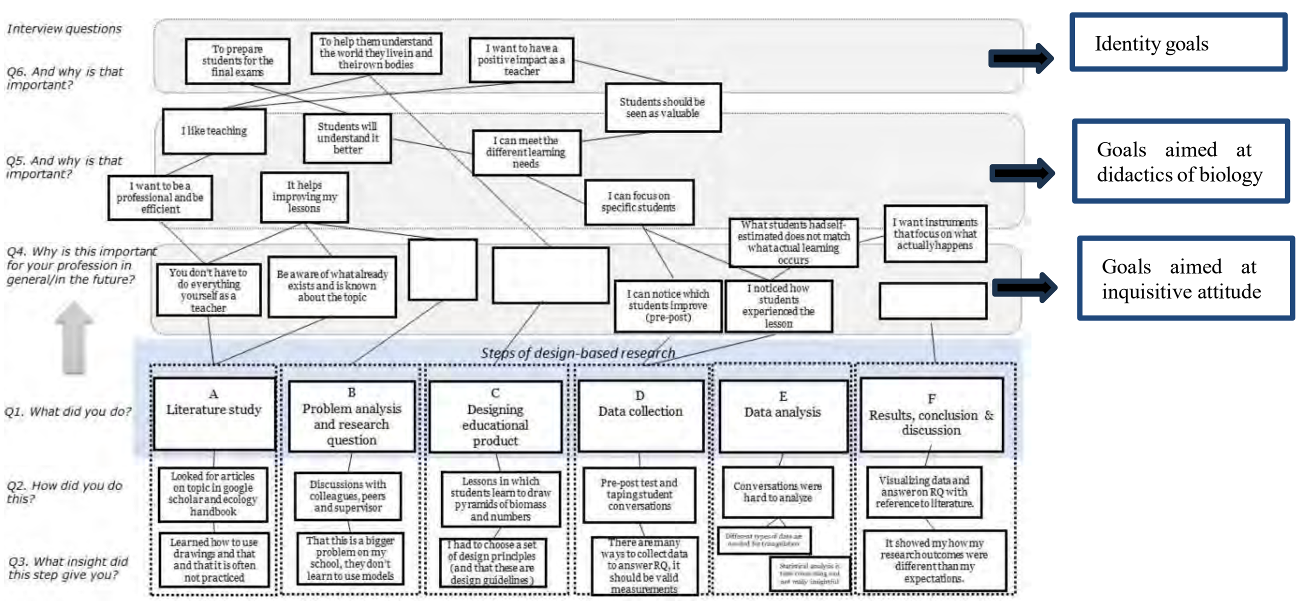
Methodology

We conducted an exploratory study involving 11 PSBT from two Dutch academic teacher education institutes. We used laddering interviews to create goal systems for the participants, which involve a hierarchical representation of goals and the reasons behind them. This method is a robust way to capture complex systems and has been used in educational research previously (Janssen, Konings & Merriënboer, 2017). We analyzed the goal systems by selecting the most important goals, clustering them into categories, and identifying the mechanisms through which lower-level goals led to achieving higher-level goals. Additionally, we determined how each research phase (A to F) contributed to the highest goals. The topics chosen for research projects by the pre-service teachers are listed in Table 1.

Table 1. Topics that PSBT chose for their research projects

Participant	Topic	Academic TE institute
1	Systems thinking in biology through the use of real animals and biological questioning	A
2	Outdoor biology education; motivation and learning outcomes	A
3	Context based ecology education	A
4	The use of academic language and subject terms in biology education	A
5	How to use flow-chart models in teaching the nitrogen cycle	A
6	Models use in teaching food webs	A
7	Learning to think in systems by creating a concept map on DNA translation	B
8	Talking in class about sex and such	B
9	How to deploy media and current events in biology classes	B
10	How to use visual models in teaching genetics	B
11	Student learning when drawing models during biology class	B

Figure 1. Laetitia's goals system about her research on student learning when drawing models during biology class



Note: some blocks are left blank to better focus the reader's attention.

Preliminary findings and conclusion

In response to RQ 1, students were quite different in which types of goals they valued most. Some students used their research project to nurture the cooperation and knowledge exchange within the team of biology teachers in the schools, whereas others were mainly focused on improving their own teaching practices. Moreover, students also differed as regards to which phases in the research process helped them most to attain their goals: some valued the process of finding, reading and using literature the most, whereas others learned the most from learning about manners in which to collect data in their own research practice. We are now in the phase of categorizing the goals and linking them to the different research activities, which will help us to tailor our research courses in the teacher training program to better suit the goals student teachers have while at the same time preparing them for their role as an academic biology teaching in school. In figure 1 (Laetitia's goals system), we illustrate the analysis. Both in the literature review (phase A) and in the data collection + analysis (phases D + E), Laetitia first indicated having goals such as 'choosing good instruments' or 'being aware of what already exists' (inquisitive attitude), followed by goals such as 'so that I can take it into account properly' (didactics of biology), followed by goals such as 'you can make a difference' (identity goal). In many of the other goal systems we analyzed we found this interesting pattern to be present. As an preliminary answer to RQ 2, we found that the phases of literature study (A), data collection
(D) and data analysis (E) had the most links to attaining higher order goals in participants' future teaching profession. Implications for tailoring TE courses and biology education in general are provided at the conference.

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Succeeding in introductory phase in biology - What factors influence the academic success of first-year biology students?

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Trainee Biology Teachers’ Self Reflection skills on their teaching lesson

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Theoretical background

There is empirical evidence attesting that reflection contributes to teachers’ improved teaching practice and expertise (Thorsen/DeVore 2013). The process of reflection includes describing, evaluating and developing alternative teaching strategies. Generating and weighing these alternative teaching strategies is considered particularly important for effective teaching (Kersting/Givvin/Thompson/Santagata/Stigler 2012). In order for (prospective) teachers to be able to consciously question and develop their teaching again and again, the practical implementation is best served in dialogue with others (Mau/Harkness 2020). Thereby “visible or sight structure of a lesson“ as behavioural, easily observable and delimitable characteristics as well as „deep structure of learning as indirectly observable characteristics are reflected (Klieme/Pauli /Reusser 2009, p. 139). In Germany, teacher training in the 1st phase at the university is followed by the 2nd phase, in which the trainee teachers teach at school and participate in the training at the Studienseminar. Already in the 1phase at university, master teacher training students of the natural science subjects at the [institute name] are promoted in diagnostics and reflection by analyzing video vignettes (author 2021). The extent to which and how these skills can also be applied on their own teaching in the 2nd phase of teacher training is being investigated in these former students who are now trainee biology teachers.

Research Questions

RQ 1 To what extent does the frequency of PCK-facettes of the pentagon model and ePCKr facets differ in elaborate and less elaborate reflections?

RQ 2 To what extent do former students who are now trainee teachers differ in terms of their diagnostic and reflection skills from trainee teachers of the same study seminar who have graduated from another university and from career changers?

Research design

Data collection took place during 2020 to 2023. The sample consisted of 28 trainee biology teachers at secondary schools in Germany in the first third (mean 6.8 ± 4.7 months) of the 2nd phase of their teacher training. A questionnaire containing socio-demographic questions, on science teachers' beliefs about diagnostic was used to collect quantitative data. A biology lessons with problem-orientation in the introduction and hands-on inquiry in the main lesson was visited by the supervisor (Fachseminarleitung) and the researcher. A reflection dialogue with the supervisor about one hour duration directly after the lesson held and after the proband had been able to reflect for her-/himself for 10 minutes was used to collect qualitative data on teachers' classroom science practices. In the first part, the trainee teacher presents all the points of the lesson and teaching actions that he/ she believes were successful and those worthy of optimization. Than a dialogue develops between the trainee teacher and the supervisor to deepen aspects and to work out the sticking points of the lesson. All lessons and dialogues were sat in by the researcher and the reflection dialogues were transcribed. For the coding process, the codes based on the pentagon model of didactic knowledge (Park/Oliver 2008) and on the three facets after Alonzo et al. (2019) were operationalized. Moreover, descriptions in chronological order of what happened in class, interpretations of the teaching situations and generating justified alternatives as well as degree of linking were coded. In this way, different levels of reflection and contrasts between the teacher study and career changer group were identified. A second rater independently applied the codes to in half of the total sample. Disagreements were resolved through adjudication, and one rater then proceeded to code the remainder of the studies.

Findings

RQ 1: Knowledge of student understanding, knowledge of instructional strategies as well as transparency in lesson structure and work assignments for students in class were the most frequently discussed topics in the reflection dialogue. In their reflections, all trainee teachers referred to "time management", which was less successful in the lessons (ePCKt). In the category "subject curriculum", most comments referred to the transparency of goals and learning objectives (ePCKp). More elaborate reflections (n= 18) referred to effective learning time (ePCKr) and educational reconstruction (ePCKp). Only these trainee teachers addressed activation of prior knowledge and task potential. When the supervisor asked for the structure and the phasing of the lesson in elaborate reflections eight of these probands mentioned the lack of orientation for the students due to intrancparency during teaching (ePCKt).

RQ 2 : In the subsequent reflection dialogue in more than 75% of the cases and in 100% of the career changers can be found the descriptions in chronological sequence of the teaching events. Career changers as well as trainee teachers graduated from another university reflected mainly sight structures of their lessons, e.g. pupils' activity and the meaningfulness of the social form of the work phases. Only in almost 40 % of the cases, besides interpretations of the teaching situation, justified alternatives were named. In only two cases did participants who had applied teacher education at university refer to alternatives that had already been discarded during the planning of the lesson. The supervisor focussed on the cause-and-effect in the holistic teaching process.

Conclusions

The findings help to uncover how trainee teachers reflect and to identify PCK aspects that they already frequently and meaningfully consider in their reflections, but also those that may be given even greater consideration for high-quality reflections. As lower levels of reflection can be characterized by referring mainly on visible or sight structure of a lesson, more reflecting dialogues about alternative and innovative teaching strategies could help to promote reflecting about deep structures of learning.

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SYMPOSIUM

Making sense of uncertainty in biology education: Issues of trust, tentativeness and complexity

Dealing with Uncertainty in Science Education - A Systematic Review on Types of Uncertainty and Ways of Dealing with Uncertainty

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Delphi study on the nature of uncertainty in science education and competencies to navigate uncertainty

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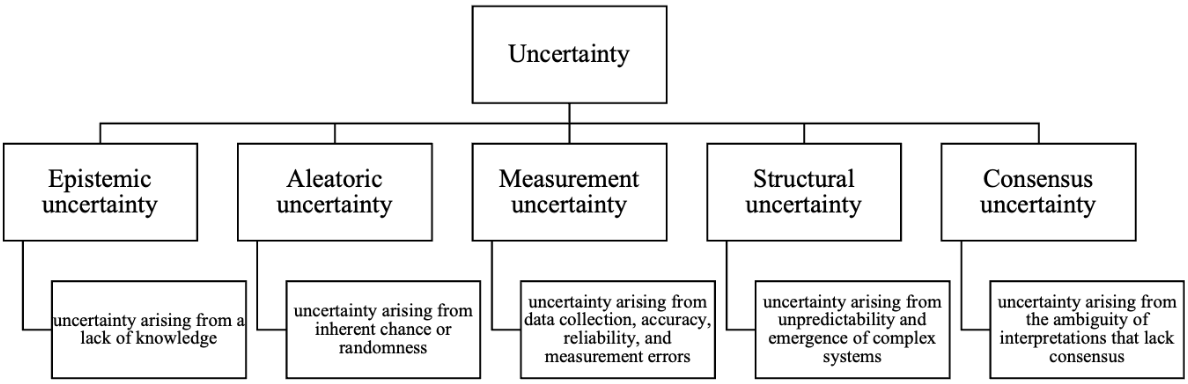
Theoretical background
Uncertainty is inherent to generating scientific knowledge (Kirch, 2012). Combing perspectives from STEM education (e.g., Zeyer, 2021), philosophy of science (e.g., Kampourakis & McCain, 2019) and science communication (e.g., Gustafson & Rice, 2019), uncertainty can be categorized as either a personal characteristic or as a characteristic of scientific cognitive process. While many types of uncertainty have been put forth (see Figure 1), there persists discourse regarding the inherent nature of uncertainty within science education (Rosenberg et al., 2022).

Figure 1

Types of Uncertainty discussed in literature

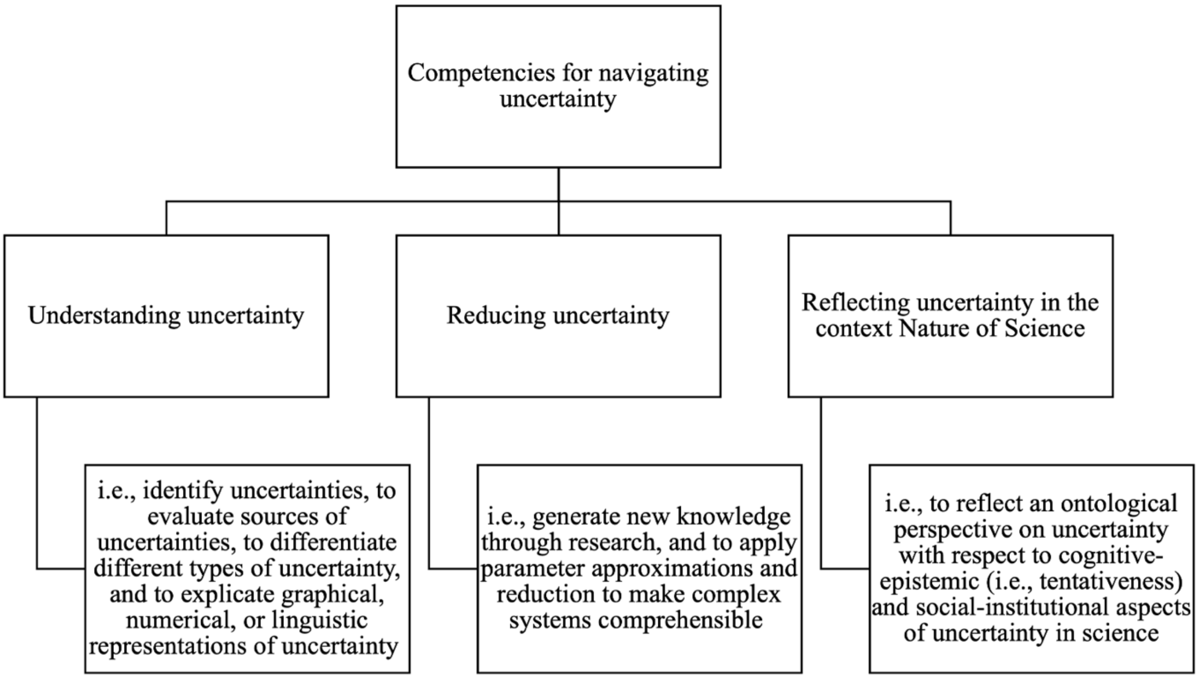


Notes. Figure based on Gustafson & Rice, 2019; Kirch, 2012; Spiegelhalter et al., 2011; Zeyer, 2021.

Understanding and effectively navigating uncertainty is regarded as learning goal in science education (Kirch, 2012). Therefore, different competencies have been discussed in literature (see Figure 2). For instance, competencies are described to *understand uncertainty* (e.g., Petersen, 2012), to *reduce uncertainty* (e.g., Kampourakis & McCain, 2019), and to *reflect uncertainty in context Nature of Science* (Author, 2021).

Figure 2

Competencies for navigating uncertainty discussed in literature



Notes. Figure based on Author, 2021; Author, in press; Erduran & Dagher, 2014; Kampourakis & McCain, 2019; Kirch, 2012; Petersen, 2012.

Key objectives

In this study, we want to explore the convoluted construct of uncertainty and competencies to navigate uncertainties in science education. For this reason, the key object was to examine the nature of uncertainty and respective competencies through expert ratings. The research questions were: *(1) What conceptions do experts from science education and scientists hold towards uncertainty? (2) What competencies are required to navigate uncertainty competently from the experts' point of view?* We specifically will highlight the perspective of experts from biology education.

Research design and methodology

Study design & Sampling. We conducted a qualitative Delphi study (Murry & Hammons, 1995) with experts from science education and scientific research to elicit a broad variety of perspectives on uncertainty. In a first step, the survey was limited to German-Speaking countries. We sourced experts from STEM education and scientific research who engage with uncertainty in their respective fields and who met the inclusion criteria (n=33, see Figure 3). Six biology education researchers participated.

Data procedures. The participants accessed theoretically derived definitions of uncertainty and competencies, before responding to three open-ended items (see Table 1). The written responses were qualitatively analyzed by three independent raters, categorizing them as "agreement," "criticism," "addition," or "disagreement." Open coding was then applied to analyze experts' conceptions and arguments, ensuring accurate representation.

Figure 3

Criteria that the experts must meet to participate

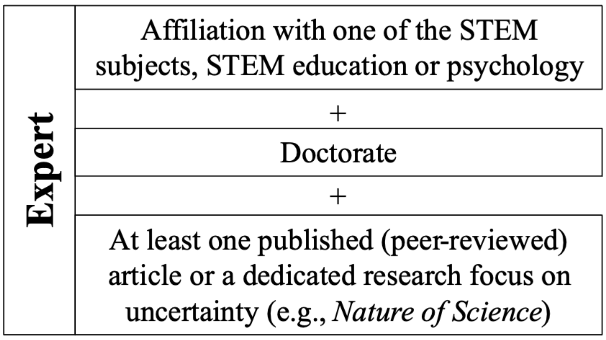


Table 1
Item list used in the Delphi study

Items to capture expert's conceptualizations of uncertainty (Part I)
1. Please explain (with the help of examples, if necessary) to what extent you agree with this understanding of uncertainty.
2. Please describe aspects that are missing in this conceptual understanding of uncertainty.
3. Please explain which of the types of uncertainty presented in this conceptual understanding (including your additions in question 2, if applicable) you consider to be particularly relevant for STEM education in schools.
Items to capture expert's suggestions for competencies for navigating uncertainty (Part II)
1. Please explain to what extent you agree with this understanding of dealing with uncertainty.
2. Please describe aspects that are missing in this understanding of dealing with uncertainty.
3. Please justify which of the competencies in dealing with uncertainty presented in this understanding (including your additions in question 2, if applicable) you consider particularly relevant for STEM education in schools.

Findings

Overall, we found that the experts largely agreed with the theoretically derived differentiation of the various types of uncertainty. The responses repeatably raised questions about the hierarchization of different types of uncertainty, described the nature of uncertainty in terms of tentativeness, and argued if it is possible to reduce the five types of uncertainty to single types. We found that understandings of uncertainty diverge widely based on the subject-specific traditions and perspectives in STEM subjects. Specifically, in biology education, ontological uncertainty, characterized by tentativeness, has been put forth as another kind of uncertainty, alongside aleatoric and structural uncertainty, which pertain to the inherent randomness and fundamental structure of complex biological systems.

Regarding competencies necessary to navigate uncertainty, we found that the understanding of competencies relevant for dealing with uncertainty in the STEM subjects diverges less than the understanding of the various types of uncertainty. Experts largely agreed with competencies described as "*understand uncertainty*" and "*reflecting uncertainty in context of Nature of Science*". The competencies described as "*strategies for reducing uncertainty*" were criticized with respect to the fact that not all uncertainties can be reduced and that it would be relevant for students to learn how to tolerate uncertainty in decision making. Specifically, in biology education, the lack of distinction between individual and collective states of knowing and the lack of contextualization have been criticized.

Conclusions

This study for the first time explored expert conceptualizations of uncertainty and competencies to navigate uncertainty in STEM education to identify similarities, differences, and avenues of further research. While there was general agreement on the importance of uncertainty and competencies for navigating uncertainty for science education, the results demonstrated that broad and diverse conceptions of uncertainty exist (e.g., Ross et al., 2013). The conceptions of uncertainty were heavily influenced by the respective research traditions per subject, leading to potentially divergent emphasis when considering the same object and raising questions on the hierarchy and the existent to which different types of uncertainty can be distinguished (e.g., Kirch, 2012). The findings highlight the need to further discuss uncertainty and competencies for navigating uncertainty from different STEM perspectives.

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Structural Uncertainty and Risk in Complex Living Systems

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Introduction and rationale
Complex and *complexity* are terms that are increasingly common in science talk, but the meaning of these terms is seldomly made explicit. Often, they are simply used to indicate a situation of cognitive overload. In the present text, complexity is discussed in terms of unpredictability and the resulting uncertainty. Although complex systems can in principle be understood by science, prediction is flawed, and control is often limited. Yet, at the same time, and this is the central message of this paper, complexity is also the very source of self- organisation in living complex systems and thus a *structural* characteristic of life itself. In other words, there is an intrinsic trade-off between life and predictability which is rarely realized in its entire scope.

Key objectives
The theory of complex living systems provides a compelling framework for working with biological contexts. It unites organisms and their natural environment in a comprehensive theoretical framework and provides a discursive resource for talking about the limits of traditional scientific approaches to scientific contexts from within science. This paper argues that, using rational argumentation, the theory gives a scientific voice to the limits of predictability in complex living systems, and to uncertainty in decision-making, which is called *structural*, because it is a direct consequence of the very structure of living systems.

Research design and methodology:
This theoretical paper is based on a in-depth consideration of the classical literature about complex systems, self-organization and ephemeral mechanisms, which was described in detail in Author (2021). Here, we point out the link to canonical theories of risk and their limits.

Findings:
Classical physics and chemistry are fundamentally the sciences of ordered systems. Most of the core physical theories - including quantum mechanics and both theories of relativity - are based on linear differential equations, and their ordered states are characterised by equilibrium solutions of these equations (Kellert, 1993). The idea that biological systems are not ordered in this sense, and that their remarkably high degree of internal order must arise in some other way, emerged as early as the 1940s, when physical and chemical scientists began to study living systems from their own point of view (Schrödinger, 1944). Living systems are characterised by autocatalysis, i.e. reaction sequences that are self-contained and in which a larger quantity of one or more starting materials is produced in the process. These are non-linear interactions and the response of the system can be much larger than the stimulus (Prigogine, 1980). In this way, autocatalytic cycles induce complexity in living systems, but - and this is the important difference from many other complex contexts - they are also responsible for the remarkably high internal order of organisms. In other words, the complexity of living systems, which brings with it problems of predictability, is at the same time essential for the underlying order-generating process, called self-organisation or autopoiesis.
Self-organisation is a strange term indeed. because it implies that the order of the system is not imposed from outside, but that the system in some sense does it itself. In this way, self- organisation plays an ambivalent role in complex living systems. On the one hand, it is the engine of ordered structures in organisms. At the level of emergent patterns, this order also produces a degree of predictability. On the other hand, the same self-organisation mechanisms inevitably keep organisms in the realm of complexity, and unpredictability is always lurking in the background of self-organisation. A tiny change in the environment, a slight shift in an autocatalytic cycle, and the hyper-connected web of physiological mechanisms can erratically assemble in singular, non-reproducible ways. Such singular, unpredictable mechanisms are also called ephemeral (Glennan, 2009). In fact, ephemeral mechanisms can appear in organisms at any time.

Conclusions:
As the Cynefin framework (Snowden & Boon, 2007) points out, ephemeral mechanisms can often be explained in hindsight, but not predicted in foresight. The application of statistical methods does not solve the problem either. The mathematics of classical statistics is linear and cannot be fully applied to non-linear contexts. Basic principles such as the law of large numbers or the central limit theorem assume linearity and do not apply in general to non-linear contexts (Yang & XIiao, 2011). From this purely mathematical point of view, linear statistics applied to non-linear contexts is highly questionable for deeply structural reasons. Such rather worrying considerations are rarely expressed in a clear way because they challenge in an uncomfortable way much of what is done in many areas of scientific research today (Ioannidis, 2005). Since prediction is central to all classical theories of risk, the aspect of structural uncertainty challenges their applicability to living systems in the same way (Zachmann, 2014). This needs to be given a proper place in the risk discourse, especially in education.

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Science distrust and epistemic uncertainty as a learning goal

Theoretical background or rationale

In recent times, we have come across a paradox: scientists' recommendations, for instance concerning vaccination, have not been met with trust, whereas they are generally considered among the most trusted professionals. For example, polls show high respect for scientists, at least higher than other institutions such as business leaders, the national government and the news media (PEW Research Center, 2020). At the same time, about eight in ten people (79%) at the global level 'somewhat' or 'strongly agree' that vaccines are safe (Wellcome Global Monitor, 2018). Why this paradox?

A reason usually given for rejecting the recommendations of scientists is science denial (Sinatra & Hofer, 2021). This is an attitude whereby people consciously overlook the suggestions of the scientific community, and believe that they themselves hold the truth that scientists either miss or want to hide. In science denial, science is questioned *a priori*: the reasoning is based on theoretical grounds, rather than on empirical observation and experience. But if most people were denialists, there is no way that scientists would rank so high in terms of trustworthiness in polls. Rather, science denial is a small-scale movement that manages to have a negative influence on many other people.

In this paper I argue that the reason for this is science distrust, a psychological situation that is distinct from science denial. Science distrust is the feeling that people cannot depend on scientists with full trust or confidence. For some people this is an awkward feeling because they end up not trusting science, even if in principle they might be willing to do so. The key difference with science denial is that in science distrust science is questioned *a posteriori*: the reasoning is based on experience, such as known facts or past events, rather than theoretical assumptions. People may thus become prone to be influenced by the arguments of science denialists.

Science denial and science distrust depend on understanding of (un)certainty in science. Broadly speaking, there are two types of certainty: Psychological certainty, when we are completely convinced that something is the case, beyond all doubt and epistemic certainty, when our evidence is so strong that it makes it *impossible* that we could be wrong. Scientific knowledge does not require epistemic certainty; actually, epistemic certainty is something that we can never achieve because the more we understand a phenomenon, the more we become aware of the uncertainties involved (Kampourakis & McCain, 2019).

Key objectives:

The objectives of tis paper are i) to argue that people who in principle would want to trust science eventually distrust it because they do not understand particular features, such as epistemic uncertainty; and ii) to draw on the history of vaccination in order to identify historical cases that could be used to teach students that epistemic uncertainty is inherent in science.

Research design and methodology:

In this paper, a historical analysis of the story of polio vaccination is used in order to identify a case that could be used to teach students that epistemic uncertainty is inherent in science.

Findings: The story of polio as a case study

In the 1950s, polio was the most feared issue in the USA after the atomic bomb. Yet, it was not the most lethal disease; in fact, it affected very few people compared to other infectious diseases such as measles. Jonas Salk was the scientist who was funded to develop such a vaccine, and who eventually managed to do this – but not without problems. There were legitimate concerns about the efficacy of the Salk vaccine, and there were also concerns about its safety, especially in the early stages. As people were familiar with the disease and its devastating effects, thousands of families in various states rushed in 1954-55 to have their children vaccinated, in order to refrain from getting polio. However, some of the vaccines used, produced by the Cutter industries, contained insufficiently inactivated virus that caused permanent paralysis or death to some of the children who received them. Overall, however, Salk's vaccine was found to be safe and effective.

However, Salk's vaccine did not stop the spread of polio virus, because it did not induce immunity in the intestine, where polio initially reproduces itself. Albert Sabin developed an oral vaccine, which induced immunity in the intestine and which lessened transmission of the virus. By 1963, Sabin's oral vaccine had replaced Salk's injectable vaccine and by 1994, polio was eliminated from the Western Hemisphere. However, the viruses in Sabin's vaccine were weakened, not killed, and could thus either cause paralysis to the people receiving the vaccine (Vaccine Associated Paralytic Polio) or reproduce in the intestines, evolving to strains that caused paralysis to unvaccinated people (Vaccine-Derived Paralytic Polio). The polio strains that evolved from Sabin's vaccine nowadays cause more cases of polio in the world than the wild-type strains.

Such uncertainty about vaccines can confuse people and make them distrust science. I suggest that we can address science distrust by explaining that this kind of uncertainty is inherent to science, and by suggesting ways to deal with it.

Conclusions:

The way that science teaching in schools has generally been done has mostly focused in fact- learning (Rudolph, 2023), despite calls for making uncertainty a learning goal in schools (e.g., Kirch, 2012). Science teaching in schools, as well as teaching curricula and teacher education programs, ought to be reconceptualized and revised, so that the students learn to deal with the uncertainty inherent in science.

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Making sense of uncertainty in Biology education: in vaccines we Trust?

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CRITICAL THINKING TO ADDRESS UNCERTAIN SSI RELATED TO BIOLOGY AND HEALTH EDUCATION

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Theoretical background or rationale
The development of critical thinking (CT) and responsible citizenship through socio-scientific contexts (SSIs) in biology education has been emphasized during the last two decade (Ratcliffe, & Grace, 2003), and more recently due to the rise of post-truth (Author & colleague, 2022). When COVID-19 was spreading among the population, the whole world was experiencing an uncertain situation that raise many questions, some still unsolved and under investigation by scientists. SSI related to biology and health education, as the COVID-19 pandemic, demands a compromised citizen capable of mobilizing scientific knowledge, valuing to make adequate choices, and participating in actions to benefit the planet, human, and environmental health. Furthermore, issues with certain degrees of uncertainty, such as COVID-19, require more developed CT to enable students and citizens to evaluate multiple perspectives of the issue (Zeidler, Berkowitz & Bennett, 2014). People struggle with uncertainty, since is not easy to assume that science does know everything about COVID-19 and that scientists may have different views on diverse questions, as we experienced. For instance, how to prevent the spread of coronavirus disease among the population. The rapid spread of disinformation through social media and the Internet makes citizens struggle to discern what is true and false (UNESCO, 2018). Therefore, as biology educators we are called to prepare students to become critical thinkers in response to this and individuals need to be critical of the topics that form their own beliefs and beliefs that affect science policy and practices to act responsibly when dealing with SSI (Bencze, Halwany & Zouda, 2020).
CT is considered as a complex competence that can be developed though the practice of argumentation but cannot be limited to the process of arguing rationally, since it also engages civic participation and social justice. Thus, CT involved commitments to a) epistemic criteria and to evidence (purposeful judgment) and, b) independent thinking and civic action (civic participation and social justice) (Author 1 and colleague, 2022). The second one is related with the notion of *critical character,* what requires dispositions, for instance, being open to other views and to revise your own position on an SSI, to assess the reliability of sources or to consider evidence. In this paper we argue that the level of difficulty in the practice of CT can vary among different contexts of argumentation on SSI. For instance, judging the arguments raised by classmates may be less difficult for students than evaluating the viewpoints presented by the media on COVID-19, since the background knowledge and argumentation skills are quite similar in the first context, whereas in the second one, the differences are high (Wan & Cheng, 2018).

Key objectives:
The purpose is to present a case study of educators as they tried to engage preservice teachers in COVID-19 vaccination as an uncertain SSI during the pandemic (before the vaccines were available for all the population) to help them to identify their views and CT on this dilemma. The research question are 1) What are preservice teachers' positions about COVID-19 vaccination in an uncertain scenario regarding the evolution of the pandemic? 2) What is the level of CT they displayed in their arguments about vaccination?

Research design and methodology:
A design was developed to engage preservice teachers in CT on COVID-19 vaccination as an SSI in a health education subject. The design was implemented during the pandemic (January 2021) in response to the high number of fake news. The study was conducted in a European country (blinded for review) with a group of elementary pre-service teachers (N=101). They worked in 20 small groups of five people. In this paper we focus on the analysis of the first task that asked them to provide arguments on COVID-19 vaccination after reading a piece of new about the first person vaccinated in their city.
The methodological approach was qualitative and followed discourse analysis methods. The analysis of CT in students' arguments was based on Brink-Budgen's model (1999). Three categories CT were coded: (a) *uncritical arguments*: low CT skills and dispositions; (b) *critical arguments*: high CT skills and dispositions; (c) *overcritical*: low CT skills and high dispositions.

Findings
Most participants (85 out of 101) were in favour of vaccination but *critical*. A small number (9) were *overcritical*, since they just questioned the vaccines but without proving reasons. An example: *"I do not know to what extent information is true, but taking news into account it is legitimate to doubt it".* The rest were *uncritical;* they accept vaccination: "*needs to be done"* to "*finish the situation of the pandemic*". Part of them referred to the uncertainty, but without expressing their understanding on the uncertain nature of science.

Conclusions
Being a critical thinker on uncertain SSI as COVID-19 requires CT skills and dispositions, but also understanding the uncertainty inherent in science (Kampourakis, 2008), what this study show.

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Posters session 1

Assessing psychological distance, content knowledge and agency in climate change education

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Theoretical background or rationale:
The measurable and tangible impacts of climate change (CC) necessitate equipping young people with the skills and competencies to address challenges related to CC (UNESCO, 2010). This requires educational development across the education system to build the subject-specific foundations to understand climate change. However, knowledge and positive attitudes alone do not always translate into self-efficacious climate actions (Kollmuss & Agyeman, 2002). Addressing this, additional low-threshold local initiatives are necessary to promote climate action (Anderson, 2012). Effective climate change education (CCE) involves fostering students' agency in tackling CC so that they are not only able to save energy but also engage in societal action (Allen & Crowley, 2017). In order to foster climate self-efficacy, it is important to consider affective components to increase engagement (Monroe, 2017) and prevent resignation (Lawrance et al., 2022). It is presumed, that knowledge about climate change is related to psychological distance from CC (Büssing et al., 2021). Since one aim of effective CCE is to make CC less "distant, global and nebulous" (Allen & Crowley, 2017) and more personally relevant, changes in the dimensions of psychological distance are of interest.
To evaluate CCE learning environments, it is important to measure the effects of interventions on involved constructs such as climate agency (Lawrance et al., 2022), content knowledge about CC (Cantell, 2019), and psychological distance to CC (Büssing et al., 2021). There are multiple instruments for measuring each of those constructs that differ in size, intended use for target groups, and context (e.g. Büssing, 2021; Lawrance et al., 2022; Tobler, 2012). To measure those constructs in students, valid interpretation of data collected with help of the instruments in terms of the underlying theory has to be investigated empirically from sources of evidence (AERA et al., 2014).

Key objectives:
This study aims to evaluate one instrument for each construct (climate agency, CC content knowledge, and psychological distance to CC) in terms of valid interpretation of data collected from a sample of German students in grades 5 to 8 with regard to the theory. The items will be modified in terms of language and wording. The validity of the interpretation of collected data in light of the theory will be investigated based on the type of cognition used, and the alignment with the intended context of the items following the Standards for Educational and Psychological Testing (AERA et al., 2014).

Research design and methodology:
For climate agency, the Climate Change Agency Scale (Lawrance et al., 2022) and for psychological distance to CC, a self-developed scale inspired by Büssing et al. (2021) will be examined. For CC content knowledge, a five-item single-choice scale has been developed. Following Leighton (2017), one-to-one think-aloud interviews with students will be conducted for each instrument with students in grades 5, 6, 7, and 8 accordingly. After testing the items for potential misunderstandings and misalignments because of wording used and linguistic characteristics, affected items will be rewritten in collaboration with language experts.
In order to distinguish between the types of cognition applied to items in the instrument, verbal analysis of think-aloud protocols will be undertaken. Data will be evaluated based on whether students' statements align with the intended context of the items.

Findings
The instrument measuring the psychological distance to CC showed no linguistic limitations. However, response processes seemed not to be aligned with the construct in every case, as approximately 1 in 5 student responses indicated the use of prior knowledge instead of solely affective cognition. To address this, concerned items were refined to explicitly emphasize the need for personal and opinion-based responses. The final results of the investigation of sources for gaining evidence for validity for measuring climate agency, CC content knowledge, and psychological distance to CC and the adapted instruments will be presented at the ERIDOB 2024 conference.

Conclusions:
The evidence-based adapted instruments will serve as valuable tools for assessing climate agency, CC content knowledge, and psychological distance to CC among students. These instruments can be used to evaluate the effectiveness of CCE interventions and guide the development of educational programs that enhance students' climate agency through self- efficacious climate action.

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Awareness about healthy sleep: a missing piece in biology education

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Theoretical background

Health literacy is an emerging subject in the field of health education (Vamos et al., 2020) and is expected to become a central theme for students on a global scale (WHO, 2013). Although a vast array of health-related information is readily available, people often lack sufficient preparation to make informed health-related lifestyle choices. The WHO (2013) refers to this dilemma as the 'health decision-making paradox', highlighting the shortcomings of educational systems in equipping students with skills to access and understand, use, and critically assess health-related information. Following Zeyer (2012), health literacy can be seen as knowledge- based competency in health-related decision-making. Based on the integrated model of decision-making in health contexts (Arnold, 2018), knowledge is a critical factor for decisions about health behaviour such as healthy sleep behaviour.

We aim to incorporate sleep education into health education for pre-service biology teachers by addressing health literacy through the concept of sleep health literacy (Beniermann et al., 2023).

Relevance for Biology Education

Along with a well-balanced diet, stress reduction, and physical exercise, sleep is essential for mental and physical health (Hirshkowitz et al., 2015). Many young people across the world are affected by chronic sleep loss (Matricciani et al., 2012). Unhealthy sleep patterns in children and adolescents not only negatively impact their physical and mental health but also their academic performance (e.g., Curcio et al., 2006).

Although sleep is one crucial factor for human health, and despite health education is one of the overarching goals of biology education in schools (e.g., Laschke et al., 2023), sleep is neither part of national biology curricula (e.g. in Canada, Germany, or the United States), nor is it addressed in common health literacy definitions (e.g., WHO, 2013). In the WHO (2013) report, sleep is not addressed at all. Several empirical studies have explored the impact of school-based sleep education programs in the field of medical education (e.g., Rigney et al., 2021), with systematic reviews demonstrating effectiveness in increasing sleep knowledge but yielding mixed results regarding improvements in sleep hygiene (Rigney et al., 2021). Moreover, the belief in sleep myths has been linked to unhealthy sleep behaviours (Pantesco & Kan, 2020). Hence, targeting sleep myths in biology lessons could prevent sleep disorders.

This lack of attention to sleep in recommendations about health literacy and health education expands over the whole research and practice field of biology education and calls for the development of sustainable sleep education approaches in schools and a conception of sleep health literacy (Beniermann et al., 2023). Sleep health literacy focuses on providing knowledge about sleep as the basis for health-related decisions. It differentiates three forms of knowledge: System knowledge, action-related knowledge, and effectiveness knowledge (Arnold, 2018). The topics 'sleep basics', 'chronorhythms', 'sleep hygiene', 'prevention of sleep disorders', and 'sleep health promotion' represent different knowledge areas of sleep health literacy.

Innovation and Transfer

The potential of sleep education is large due to its relevance for health and children's interest in sleep-related questions (Swirski et al., 2018). However, most intervention studies lack a necessary theoretical foundation (Rigney et al., 2021) for ensuring evidence-based programs. To address this gap, the concept of sleep health literacy (Beniermann et al., 2023) can provide a standardized theoretical foundation for future empirical studies.

Integrating sleep education into biology lessons faces several barriers, primarily the lack of training and knowledge among biology teachers about sleep hygiene and effective interventions (Gruber et al., 2019). Since sleep is not typically part of biology teacher training, we recommend incorporating sleep education into pre-service teachers' health education.

At the ERIDOB 2024, we will present this approach based on the concept of sleep health literacy and address common sleep myths.

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Can Citizen Science Foster Biodiversity Knowledge, Nature Connectedness and Biodiversity Action of Secondary School Students?

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Rationale and theoretical background

The global biodiversity crisis (IPBES, 2019) increasingly threatens the well-being of human populations (Díaz et al., 2006). As the rapid loss of biodiversity is due to anthropogenic influences, great conservation efforts are needed (Lampert et al., 2023). In order to integrate sustainability principles into all levels of education, formal education should include local engagement of students with sustainable development organizations (UNESCO, 2014). In this context, *Citizen Science (CS)* is gaining importance, as it fosters active public participation in scientific research while supporting local conservation e.g., through species monitoring (Dickinson et al., 2012). In addition to these outcomes, *CS* can also be fruitful for the participants themselves by providing space for nature exploration (Moormann & Sturm, 2021) and increasing species knowledge, interest, motivation, and self-efficacy regarding the environment and biodiversity (Peter et al., 2021). In formal education, *CS* projects can engage students in real scientific processes such as observation, collection, or processing of data and thereby help to clarify the *Nature of Science*.

As our study focuses on pro-biodiversity behavior, we refer to approaches from environmental psychology: The *Comprehensive Action Determination Model (CADM)* attributes the willingness to act in a nature-protecting way to personal factors e.g., attitudes (Klöckner, 2013). The *Social Identity Model of Pro-Environmental Action (SIMPEA)* extends the *CADM* by the collective variables *"identification with a group"*, *"perception of a pro-conservation social norm within the group"* and *"belief about the collective efficacy of the group"* (Fritsche et al., 2018). *SIMPEA* reasons that personal conservation actions are implemented when one's actions are understood as part of a collective movement (Hoppe et al., 2023).
In contrast to informal settings for *CS*, the state of empirical research on *CS* in school education is very limited (Hecker et al., 2018). Target variables such as interest and self-efficacy are usually categorized as factors of individual thinking and experience (McKinley et al., 2017). Very few studies exist that consider the importance of identification with pro-environmental social groups in explaining conservationist behavior. Masson et al. (2023, accepted) found that a *CS*-oriented treatment on urban biodiversity in higher secondary classes not only led to an increase in knowledge and nature connectedness but also fostered both students' collective and personal biodiversity conservation behaviors and intentions to act collectively.

Key objectives

Our central research question examines the extent to which participation in a local biodiversity- based *CS* project in regular biology classes can promote (i) biodiversity knowledge, (ii) nature connectedness and (iii) personal and collective variables toward conservation.

Research design and methodology

A quasi-experimental control group design consisting of pretest, posttest and follow-up is planned with students at two secondary schools in Leipzig. The control group will be instructed on urban biodiversity and explore local biodiversity hotspots in field trips, guided by experts. The experimental group will undergo the same treatment, but in addition, data collection and analysis will contribute to a local *CS* project on biodiversity that has been introduced to them during the instruction.
The effectiveness of those treatments will be measured and evaluated through open and closed items aiming at biodiversity knowledge, nature connectedness and a variety of other individual plus collective outcome variables adapted from the *Connectedness to Nature Scale* (Mayer & Frantz, 2004) as well as other established instruments.
By the end of 2024, the questionnaires will be created and tested for their quality in a pilot study, in order to optimize them accordingly.

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Knowledge of Native Species by Prospective Biology Teachers A Quantitative Study to Determine Species Knowledge

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Theoretical background or rationale:
Knowledge of species is a prerequisite for understanding natural and ecology in general (Randler, 2008). Species knowledge goes hand in hand with a high potential for nature conservation (Berck & Graf, 2018) and biodiversity education (Sturm & Berthold, 2015). Teaching knowledge of species is mainly done in the school subject biology (Lindemann- Matthies & Remmele, 2021). Research indicates that exotic species are usually better known than native species (Genovart et al., 2013). In Germany, knowledge of species among schoolchildren has also declined in recent years (Gerl et al., 2021), with the lack of teacher qualifications being one reason mentioned (Frobel & Schlumprecht, 2016; Krüger et al., 2010). However, there is a lack of scientific findings in this regard.

Key objectives:
This study aims to find out how pronounced the species knowledge of prospective biology teachers is. Therefore, student teachers were asked about their species knowledge of the Wadden Sea. This UNESCO World Heritage Site is a native ecosystem in Germany and an important part of the world's largest contiguous mudflat area (Reise et al., 2010). It is the habitat of over 10,000 species of animals, plants, and fungi (Hofstede & Stock, 2018). In addition to the extent of species knowledge, we also determine how well known individual species are.

Research design and methodology:
A total of 206 students at Bielefeld University participated in the study. The mean age of the respondents was 23.4 years (*SD* = 2.59), and 67% of the participants were female. In an iterative process with experts, a total of 18 different species of animals characteristic of the ecosystem were selected. The respondents were presented with a colored scientific drawing for each of the species. Thus, knowledge of a species is equivalent to identifying that species from the corresponding drawing. The selection of the analysis procedure was guided by the implementation in other studies that have considered species knowledge (Randler, 2006; Sturm et al., 2020). One point was given for mentioning the correct species name. If a superior taxon was correctly indicated, half a point was assigned.

Findings:
Students scored an average of *M* = 5.41 out of 18 on the survey (*SD* = 2.93). Table 1 shows the scores achieved by respondents for each species. The scores obtained by all participants for each species were summed, resulting in a range of scores between 0 and 206 for each species.

Table 1: The presentation of the results according to the species.

Species	Points	Percent
Larus argentatus	146	70.87
Cerastoderma edule	101,5	49.27
Pagurus bernhardus	94.5	45.87
Phoca vitulina	91.5	44.42
Carcinus maenas	91.5	44.42
Mytilus edulis	89	43.20
Arenicola marina	75.5	36.70
Phocoena phocoena	70	33.98
Halichoerus grypus	59	28.64
Crangon crangon	58	28.16
Haematopus ostralegus	53.5	25.97
Hydrobia ulvae	51.5	25.00
Mya arenaria	50	24.27
Buccinum undatum	26.5	12.86
Numenius arquata	21	10.19
Littorina littorea	18	8.74
Hediste diversicolor	13	6.31
Lanice conchilega	4.5	2.18

Conclusions:

The finding of a low ability to identify locally common species of prospective teachers as well as the deficiencies reported by university teachers (Krüger et al., 2010) can be strengthened. Even with a reference to the Wadden Sea, this result is unsurprising. Thus, in a word association study it became clear that this ecosystem is partly linked with professionally incorrect terms by prospective biology teachers (Schmäing & Grotjohann, 2022). Although herring gull is a very characteristic bird for the Wadden Sea, it also occurs inland. So, the high awareness of this species could be a consequence of its distribution outside the tidal flat region.

The results show that it is important to promote the knowledge of species among prospective biology teachers in university courses and excursions. Only in this way will it be possible for them to teach their students this relevant content in their own lessons and to sensitize them to the protection of native ecosystems.

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Promoting biodiversity-enhancing behavior through the transformative research method: `challenges´

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Theoretical background or rationale:
The central focus point for initiating our project is that human actions are dismantling the earth's ecosystems, eliminating genes, species, and biological traits – and consequently, resulting in impacts on humanity (e.g. IPBES 2019). Nevertheless, the general public is mostly not aware of this biodiversity loss – despite costly projects and major campaigns (BMU 2021) and even if they are aware often no action is taken. Many approaches have been developed to explain the gap between environmental awareness and action (Diekmann & Preisendörfer 1998, Bamberg 2003). However, these could not satisfactorily solve the basic problem of this discrepancy.
To investigate social change towards sustainability we see transformation research as a promising research perspective. One transformative research method are "Challenges". Specific tasks are given to the participants which should motivate them to modify their behavior and engage in activities. We consider relevant theories, such as the theory of planned behavior (Ajzen 1991) and the Fogg Behavior Model (Fogg 2009), when developing the challenges. The challenges will be carried out using a mobile application, which offers users autonomy by allowing them to choose from a variety of challenges and decide when to begin them. This autonomy can enhance intrinsic motivation according to the self-determination theory (Ryan & Decy 2000a). Additionally, to motivate participants, we use gamification elements which are game elements and mechanics used in non-game contexts (e.g. Deterding et al. 2011). While some critics argue that it could be reduced to collecting "empty" virtual rewards, a literature review by Seaborn and Fels (2015) consistently positions gamification as a tool that effectively enhances both extrinsic and intrinsic motivation (Ryan & Deci 2000b).

Key objectives:
Transformation research is a promising research perspective to investigate social change towards sustainability. We want to test under which circumstances the transformative research method Challenges can be used to anchor sustainable changes in daily life. We will investigate optimal duration of challenges, use of notifications and different gamification elements. Additionally, we want to assess the difficulties and obstacles that prevent users from completing the Challenges.

Research design and methodology:
Our research project is part of a cooperation project called "From Insight to action". In this project as a first step for solving the transformation challenge, the focus is on nature experience and subjective reflective processes on nature and biodiversity. In the second step, these experiences will be experimentally transferred into social practice with the help of transformative research methods (e.g. Challenges).

In our part of the project, we focus on these Challenges. Not many studies have used Challenges as a research method to motivate people to change their behavior. Therefore, our aim is to investigate the conditions under which they prove effective and the optimal design and implementation approaches. We will gather data through pre-, post- and follow-up questionnaires and interviews.

We introduced 22 different tasks covering the topics nutrition, biotope/habitats, animals, natural dynamics, consumption and mobility. The challenges were on one hand selected according to the criteria which are crucial for preserving the biodiversity according to the Federal Nature Conservation Act of Germany (Bundesnaturschutzgesetz 2009). On the other hand, we took into account which social practices are causing the most damage to the biodiversity, which is primarily nutrition and comestible goods (BMU 2023).
We use the German mobile application "H.O.P.E." to facilitate our activities. The app is designed to motivate users to combat climate change and includes an area dedicated to our project, where participants can access the Challenges. The app enables self-tracking and incorporates gamification elements like earning points upon challenge completion. A ranking system showcases top-performing users, and notifications are sent to remind users to engage with the app and complete challenges.
We measure success based on the number of Challenges completed in practice. Furthermore, another success indicator will be the scientific findings on the conditions of the Challenges, i.e. the knowledge

about achievements and obstacles, which will be collected through questionnaires and qualitative interviews. We are using questions from the BMU (2023) Nature Awareness Study to assess biodiversity knowledge, public awareness of biodiversity loss, and intentions to act on it. In a post-questionnaire and interviews, we want to document the challenge difficulty and reasons for not completing a challenge. We also want to assess if completing challenges motivated users to continue contributing to biodiversity conservation.

Findings:
First data will be presented at the conference.

Conclusions:
In conclusion, it is worth considering how the method of challenges could be utilized as a tool to transform attitudes and actions to support greater biodiversity protection.

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Upper secondary school students' perceptions of circular economy and recycling in a rural school setting

Anne Laius and Merike Kont

Urban Environmental Education and mobile technology: Development and evaluation of an environmental education trail in the city with the use of QR codes for student teachers

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Introduction
Urban environmental education (EE) is becoming increasingly important as more than half of the world's population reside in urban centers, a number expected to rise further (Russ & Krasny, 2017). Cities face many environmental problems, however they are also places for learning about nature such as urban fauna and flora and man- nature interactions and interdependence (Leou & Kalaitsidaki, 2017). Recently mobile technologies have been applied to EE to enhance exploration, inquiry and data collection, both in formal and informal settings(Shmulenson etal, 2015). However issues have been raised about its use in EE regarding teachers' technological literacy, issues of access since some tools are expensive, its usability in the field as screens may be difficult to read in the sun, or in the rain, , strength of internet connections which must be taken into consideration by educators (Shmulenson etal, 2015).
Environmental trails, a traditional EE method, are organized itineraries designed by the teacher for the purpose of observing and exploring different aspects of natural or built environment. They focus on specific points of interest where students are asked to conduct activities such as record data, fill worksheets, take photographs, identify biodiversity, and practice various skills (observation, taking measurements, making comparisons, reaching conclusions and critical thinking).
This paper presents the development, implementation and evaluation of an urban environmental education trail inside a city's municipal garden that was developed according to the principles of place based education (Sobel, 2006), the urban environmental education trend to use the city as a classroom (Russ & Krasny, 2017) and the guidelines for excellence for non-formal EE programs (NAAEE, 2009). Moreover, we wanted to try the use of mobile technology in particular Quick response codes that have been used previously successfully in EE (Kalogiannakis & Papadakis, 2017).

Methodology
The study had three phases: a)development of the trail b) implementation with 6 student teachers. c) evaluation of the trail

a) Phase A

We set the following objectives for the EE trail:
a) to promote knowledge on the local environment (local biodiversity and local environmental problems).
b) to establish the city's municipal garden as a place for teaching and learning
c) to integrate mobile technologies with EE to achieve learning outcomes
d) to promote the method of an environmental trail to perspective teachers so that they use it themselves in the future.

We conducted site visits, read books by local writers on the municipal garden's history. We also searched for newspaper articles concerning the local environment, and reports of local environmental problems. It should be noted that "local" in place- based education can be defined as one's neighborhood, the city they live in, or even a larger division (prefecture), or for island communities like ours, the whole island..
The final trail had 14 stops within the municipal garden , 5 stops focusing on plants, 3 stops with animals, 3regarding local environmental problems , 2 stops with culture and the arts and 1 stop on the garden's history. At each stop information and activities was provided through QR codes to be read by the participants' smart phones connected to a 4G network.

b) Phase B

The EE trail was pilot tested in May 2022 with 6 students of the department of primary education, 5 females, 1 male that came from the city who participated voluntarily, they gave written consent to take part in the study and be interviewed.

c) Phase C

Evaluation of the trail, was outcome-based (Thomson, Hoffman, Staniforth 2010). The research question were whether the objectives of the trail had been met. Specifically
-Had the students appreciated the municipal garden as a place for learning?
-What was their opinion on the method of an environmental trail as future teachers?
-How they evaluated the use of mobile technology?
-What they had learned from the trial?

Data were collected through semi-structured interviews and participatory observation. Interviews were conducted through teleconferencing, were transcribed and analysed thematically (Braun & Clarke ,2006).

Findings-Conclusions

All participants appreciated the EE trail method and would like to apply it in the future. Regarding the use of mobile technology, they all expressed satisfaction with the use of QR codes and the use of their smartphones albeit occasional small technical problems. However one participant stated that she will not use technology with her students in the future, as she is concerned with the amount of time children spend nowadays with electronic devices. They all appreciated the municipal garden as a place for learning which they had not before. While talking about what they had learned they acknowledged skills such as observation, taking measurements, making comparisons, reaching conclusions and critical thinking but they did not refer to any of the local environmental problems that we had included in the trail. Nor did they mention any of the plants by name, however they did enjoy the use of the Plant net application we had incorporated in the trails activities. We conclude that the application of mobile technology to EE is effective, engaging, and could renew young people's interest to the study of the local environment.

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Argumentation about transgenic foods by pre-service biology teachers. A case study.

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Theoretical background or rationale
Socioscientific problems involve everyday issues where science and technology are key (Acar et al., 2010), such as climate change, vaccines or transgenic foods. Addressing them through education helps develop critical thinking skills, prepares students to be informed and ethical citizens, and empowers them to engage in debates and make decisions about issues that affect them personally and globally.
Debate is an effective strategy for addressing socioscientific problems in the classroom through active learning (Bruguière et al., 2014). They offer broad benefits, ranging from developing communication and critical thinking skills to promoting empathy and active social participation (Triana et al., 2014). Among communication skills, debates foster oral expression and the ability to articulate arguments clearly and persuasively. Regarding critical thinking, debates require students to search for information, research, analyse and evaluate arguments, encouraging evidence-based decision-making (Jiménez-Aleixandre, 2010). Finally, they foster empathy and tolerance by helping to understand multiple perspectives on a problem and respecting the opinions of others.
This work presents the results of a debate with pre-service biology teachers about transgenic foods, raising societal concerns about whether scientists are modifying nature, the possible environmental and health damage, or the quality of the food (España & Rueda, 2023).

Key objectives:
This study aims to find out the argumentative quality of pre-service biology teachers, before and after attending as listeners to a debate on the problem of genetically modified food.

Research design and methodology:
The study sample consisted of 31 pre-service biology teachers (19 women and 12 men) for the master's degree in Secondary Education at the University of Malaga (Malaga, Spain) for the 2021-2022 academic year. The pre-service teachers were participating in a training programme to improve their critical thinking skills and had received instruction in argumentation.
These students listened to a debate on transgenic foods by three classmates. One was in favour, one was against, and the third was the moderator with a neutral position. The debate was structured as follows: an initial minute's intervention by each debater, a five-minute debate, and a final minute for conclusions.
The data collection instrument was a question (Would you be for or against the consumption of transgenic foods?) posed to the listeners of the debate as a pre-test and post-test. The arguments given by the pre-service teachers were analysed according to Toulmin's model (1958), identifying the conclusion, evidence and justification for each argument. In the case of the conclusion, we studied whether it existed or was in doubt. We studied their typology and number for the evidence, calculating the participants' mean. Justifications were analysed using a rubric with three levels (0: no justification, 1: ambiguous and imprecise justification, 2: precise and concrete justification).

Findings:
Before the debate, all pre-service teachers stated a conclusion (28 in favour and 3 against). However, 13 hesitated to state this conclusion (12 for and 1 against). After the debate, all pre-service teachers maintained their initial conclusion, with only 4 pre-service teachers hesitating (3 for and 1 against).
The mean number of evidence per pre-service in the initial arguments was 1.65 (51/31), with biological and other evidence found. These biological evidence were related to environment (mean: 0.32, 10/31), health (0.45, 14/31) and nutritional properties (0.26, 8/31). Other evidence used were socio-economic (0.35, 11/31) and opinion (0.19, 6/31).
After the debate, the average number of evidence per pre-service increased to 2.16 (67/31), using the same types of evidence plus legal ones (0.06, 2/31). Also, the average of all types of evidence increased: environmental (0.58, 18/31), health (0.48, 15/31), nutritional (0.32, 10/31), socio-economic (0.52, 16/31) and opinion (0.23, 7/31).
The average number of justifications per pre-service before the debate was 0.74 (10/31 pre-service teachers reached level 2 in justification), while after the debate, it rose to 0.90 (13 pre-service teachers at level 2). Notably, 17/31 pre-service teachers before and 16/31 after the debate did not include justifications

in their arguments (level 0).

Conclusions:
The study concluded that the quality of the arguments of pre-service biology teachers needs to be improved. While it is true that, after attending the debate, we could observe progress in the number and type of evidence provided and a reduction of doubts in the conclusions, the absence of justifications in the arguments of 50% of pre-service teachers after the debate is a matter of concern. To improve the argumentative quality of the pre-service teachers, it is essential that they carefully analyse their arguments and make proposals for improvement.
This work is a preliminary study of argumentation on socioscientific problems related to biology, and its results will be used to design mobile applications that promote scientific argumentation.

Acknowledgements:
21ProyExcel_00176 of the Andalusian Plan for Research, Development and Innovation (PAIDI 2020). Educational Innovation Project PIE22-184 of the permanent group EDUCRIT, funded by the University of Malaga, INNOVA22 call for biennium 2022-2023 proposals.

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Using Role-Playing to Enhance Scientific Argumentation in Secondary School Students on Environmental Issues

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Theoretical background or rationale

We are currently facing a situation of severe deterioration of the planet caused by human actions, as well as serious situations of social injustice and a regression of democratic rights (Reis, 2021). The conflict between Russia and Ukraine has brought to the forefront a major energy problem in Europe — dependence on fossil fuels— with implications for the environment, the economy, health, and public safety.

When scientific knowledge is insufficient or fails to bridge the gap with real-life situations, individuals may resort to personal opinions and beliefs instead of relying on a solid scientific understanding when forming arguments (Macagno & Konstantinidou, 2013). Therefore, it is essential for citizens to acquire a strong foundation in scientific knowledge that enables them to actively address these issues, transforming into informed and engaged members of our society (Reis, 2014).

Employing role-play as an educational strategy offers the opportunity to blend the elements of gameplay, the simulation of contemporary social and political scenarios, argumentation and dramatization to encourage students to explore socio-scientific issues (McSharry & Jones, 2000). Argumentation involves drawing conclusions based on verifiable evidence and prior knowledge, following the Toulmin model (Jiménez-Aleixandre & Puig, 2010; Toulmin, 1958).

One of the most prevalent approaches in science education for developing argumentation skills in the classroom is the well-established Toulmin model (Toulmin, 1958). This model comprises the essential components of an argument, including conclusion, evidence, warrant, refutation, and backing. For simplicity, the framework can be reduced to three fundamental elements: conclusion, evidence, and warrant (Jiménez-Aleixandre, 2010). In this study, our focus will be on the evidence students use to support their positions on a specific environmental problem.

Key objectives:

The objectives of this study are as follows:

- To determine the topics addressed in the evidence that students use to support their roles in an environmental problem role-playing scenario.
- To assess the quality of the evidence employed by students in constructing their arguments.

Research design and methodology:

In this study, a role-playing game was carried out, where students represented a congress, with different parliamentary groups. Each faction had to argue for an alternative energy source instead of purchasing Russian gas, such as wind energy, solar power, hydropower, tidal energy, geothermal energy, or continuing to buy gas from other countries. Students were required to construct arguments to support their roles during the role play.

The educational proposal was implemented with 62 students, aged 13-14, enrolled in the compulsory Chemistry course at a secondary school in Malaga, Spain. These students were part of two class groups, each consisting of 31 students.

For data analysis, the role-play was audio-recorded and transcribed. The arguments were then categorized based on the themes of evidence. The students' evidence was grouped into three categories: high quality (concrete and accurate), medium quality (based on experiences or containing inaccuracies), and low quality (incorrect, questionable, or subjective).

Findings:

Evidence themes

Students constructed a range of arguments to support their roles (Table 1). Of these arguments, 41.18% addressed environmental concerns, such as the following statement: 'We support tidal energy because it is a clean and renewable source that does not generate pollutants or greenhouse gases, offering an eco-friendly alternative to fossil fuels like petrol.' [Parliamentary group in favour of tidal energy].

Table 1. Categories addressing the students' arguments.

Categoríes	Frequency (%)
Enviromental issues	41.18
Economic issues	13.25
Social issues	10.29
Energy stability	10.29
Geopolitical issues	7.35
Energy efficiency	7.35
Security issues	4.41
Health issues	2.94
Other	2.94

To a lesser extent (13.25%), the arguments addressed economic issues (e.g., 'The construction of wind farms and wind turbine installations generates significant job opportunities, contributing to the country's economy' [Parliamentary group in favour of supporting wind energy]).
Arguments related to social and energy stability occurred with a frequency of 10.29% each. There were also arguments related to minor issues, including geopolitical concerns and energy efficiency (7.35% each), security (4.41%), and health and miscellaneous topics (2.94% each).

Quality of evidences

53% of the evidence was of the highest quality, featuring concrete and accurate data (e.g., 'It's worth noting that a single tidal power plant in South Korea can supply electricity to half a million households, generating approximately 254,000 kW per day. As a result, South Korea has significantly reduced its CO2 emissions' [Parliamentary group in favour of tidal energy]).

40% of the evidence was of medium quality, featuring some inaccuracies or descriptions of personal experiences (e.g., 'Maintenance is almost negligible, with only personnel required for construction' [Parliamentary group in favour of solar energy]).

Only 7% of the evidence was of low quality, characterized by inaccuracies, questionable claims, or subjectivity. Most of the incorrect evidence was employed to support the position of continuing to purchase natural gas from another country, as exemplified by the statement: 'Natural gas does not pollute like other energy sources' [Parliamentary group in favour of the purchase of gas].

Conclusions:

The climate emergency demands innovative educational approaches to tackle these pressing issues. Role-playing games enable students to articulate well-founded perspectives on environmental matters, including a country's energy sources, their environmental impact, and their capacity to meet societal needs. In future work, we are focused on developing mobile applications for scientific argumentation using the data presented here.

Acknowledgements:

21ProyExcel_00176 of the Andalusian Plan for Research, Development and Innovation (PAIDI 2020). PIE22-184 Funded by the University of Malaga, IINOVA22.

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Implementation and evaluation of an in-school student laboratory using Design-Based- Research

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Theoretical background/rationale:
Particularly over the last years, *Design-Based-Research* (DBR) has been used to decrease the discrepancy between theoretical-driven research projects and practical-oriented needs of educators. DBR combines the development of innovative solutions for educational problems with gaining empirical insights into the problem and its possible solutions (Shavelson et al. 2003). This is achieved by focusing on two goals at the same time: on the one hand, DBR is centered around solving educational problems brought up by educators; on the other hand, DBR strives to develop new or to refine theories about education (Lehmann-Wermser & Konrad 2016). Hence, there is a benefit for both researchers and practitioners at the same time (Ruthven et al. 2009).
In cooperation with a local vocational school, we plan an in-school student laboratory in order to increase the number of experiments conducted in the biology lessons. In line with the DBR process, practitioners from that school work together with researchers to develop a concept, teaching materials and experiments as well as an evaluation for the planed in-school student laboratory. The in-school student laboratory is carried out in a special room in order to leave the regular classroom. Additionally the lab-activities are guided by specific teachers and, hence, the laboratory is set in a special atmosphere different from the regular biology lessons. However, at the same time it is not a classical out-of-school student laboratory since the students to not leave their usual learning environment (school).
Numerous previous studies have investigated the effects of out-of-school lab-based lessons. The results of these studies indicated that out-of-school learning environments increase not only students' general interest in science, but also various dimensions of it, such as emotional interest or value-related interest (e.g., Engeln 2004, Brandt 2005, Pawek 2009, Röllke 2019). However, it is unclear to what extent those effects can be achieved in an in-school student laboratory.

Key objectives:
The project has multiple objectives, which can be broadly divided into two key objectives: firstly, we want to investigate effects of in-school laboratories in terms of elements of perceived constructivism (e.g., active participation, social interaction and constructive behavior), while simultaneously addressing the affective factors of interest and frustration, as well as self-concept and content knowledge. Secondly, we want to investigate potential benefits of DBR-projects for both schools/ teachers and researchers.

Research design and methodology:
The design process of the in-school laboratory follows a design-based-research approach. DBR is an iterative process that combines developing interventions with evaluation (Plomp 2013). DBR research follows a specific procedure which can be divided into four phases.
In the first step, researchers and practitioners investigated the current state-of-the-art of student laboratories, school equipment, teaching curricula, etc. in order to decide on possible protypes. The development of those protypes – in this case the one-day workshops in the school laboratory – is the second step of the DBR cycle. Currently, protypes for a workshop about enzymes and genetics are being developed. This also includes a questionnaire to evaluate the workshops concerning different factors, such as interest, content knowledge, etc.
Both the workshop materials and the evaluation are needed for the third step, which is the investigation phase consisting of the intervention, the evaluation and the revision of the materials. The steps of this phase will be repeated until a sufficient result is achieved. The first investigation phase will start in February 2024. We aim at having both workshops completed and evaluated by at least 4 classes each (ca. 80-100 students). For the evaluation students will be asked to complete a mostly quantitative questionnaire some weeks before the intervention in the in-school laboratory and right after completing the workshop. Furthermore, it is planned to include a control group of students, who are not participating in the workshop as well. The results of the first investigation will be presented in the planed poster presentation at the conference. The last phase of DBR research is the "solution", which will be stated at the end of the research project.

Findings and Conclusion:
Not yet applicable. First selected results will be ready for presentation in summer 2024.

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Exploring Pedagogical Potential of Climate Change
Exhibits in Natural History Museums

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Gender and age as factors in the implementation of outdoor education programmes

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Theoretical background or rationale

Environmental attitudes, values, concerns, and connectedness to nature are often measured to determine individual student preferences. Outdoor education programmes for children and youth are recognised as important educational interventions that affect children's environmental attitudes and concerns (Bogner & Wiseman, 2004; Braun & Dierkes, 2017; Liefländer et. al., 2013). Torkar et al. (2021) report that environmental attitudes of Slovene primary school students decrease with age, while altruistic environmental concerns increase with higher grades.

Wiseman and Bogner (2003) introduced a scale to assess ecological attitudes that includes two main dimensions: Conservation (PRE) and Utilization (UTL). PRE represents a biocentric perspective that emphasizes conservation and protection of nature, whereas UTL embodies an anthropocentric dimension that emphasizes exploitation of natural resources. Environmental values and concerns, as articulated by Schultz (2004), are characterized by three categories: Egoistic (EGO), Biospheric (BIO), and Altruistic (ALT). EGO primarily pertains to self-centered goals and priorities, while BIO reflects a broader concern for all living beings such as plants, animals, trees, and birds. ALT, on the other hand, signifies a social concern directed toward humanity, family members, and friends (Schultz et al., 2004; Torkar et al., 2021). According to Cheng and Monroe (2012), connectedness with nature can be operationalized through four fundamental constructs: Enjoyment of Nature (EN), Empathy for Creatures (EC), Sense of Oneness (SO), and Sense of Responsibility (SR). EN focuses on activities and emotional experiences related in nature, while EC includes emotions and compassionate care for animals and plants. SO refers to inclusion of humanity in the natural world, and SR represents the impact of one's actions on the natural environment (Cheng & Monroe, 2012; Bezeljak et. al., 2023).

Key objectives

We aimed to investigate the attitudes of Slovenian youth towards the environment and the importance of participation in a one-week programme in Centres for School and Outdoor Education (CSOD) for the development of their environmental attitudes, concerns, and connectedness with nature. The main research objectives were to examine gender and age differences in their environmental attitudes before and after participation in outdoor education.

Research design and methodology

The intervention was implemented in the 2022/23 school year. 702 students (female: 50.3%) aged 10 — 15 years participated in a five-days long outdoor educational programme (the locations of the centres where the study was conducted are marked in red in Fig. 1). The programme consists of three components: academic content (science subjects, sports, social sciences and arts), recreational activities (for relaxation and pupil engagement) and other activities (involving nutrition, personal hygiene and daily chores).

They completed a questionnaire on the first and last day of the outdoor education programme.

The instruments used were: 2-Major Environmental Value Model (Wiseman & Bogner, 2003), Connection to Nature Index (Cheng & Monroe, 2012), Environmental Motives Scale (Schultz et. al., 2004).

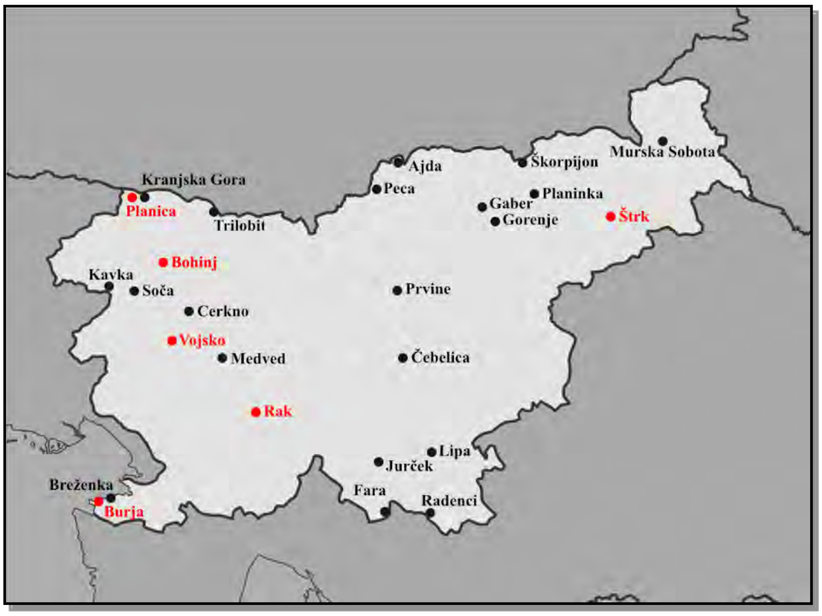

Figure 1. Centres of outdoor education in Slovenia (CSOD).

Findings

The results in Fig. 2 show that environmental attitudes (preservation – PRE, utilization – UTL), concerns (egocentric — EGO, altruistic — ALT, biocentric — BIO) and connection to nature (enjoyment of nature — EN, empathy for creatures — EC, sense of oneness – SO, sense of responsibility — SR) between male and female students changed in favour of the latter. The difference between the sexes continued to increase after the programme.

The results presented in Fig. 3 show the difference in the students' perception of the environment compared to the age group 1: 10—11 years, group 2: 12—13 years, group 3: 14—15 years. The statistically significant changes were found between age groups 1&2 and 1&3 (PRE, BIO, ALT, EGO, EN, EC, SO, SR), while the differences between group 2&3 were not statistically significant in any of the measured dimensions. This may indicate that there is a turning point in students' perception of nature between ages 10-11 and 12-13, as shown in Fig. 3. No significant changes were found on the last day of the programme (second sampling — darker colour).

In-School and Out-of-School Biology Learning – Do Their Educational Objectives Show Common Ground?

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Scientific dissemination activities between uminho biology and school students

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Theoretical background

Extension activities are crucial for universities as they enable dialogue between intra- and extra-academic circles (Marandino, 2013). Dissemination of science is one of those activities which has the potential to share and clarify the construction of scientific knowledge for society, bringing to light the tentative and collective aspect of scientific endeavour and the myriad of influences and problems that run through it.

In addition to questions related to "why" and "how" to disseminate, the profile of the science communicator is also a subject of discussion (Marandino et al., 2003). While some argue in favour of scientists or journalists, we further highlight the work of higher education students. By interacting, for example, with basic schools through science communication activities, it is understood that undergraduate and postgraduate students learn from an early age to deal with decoding the subjects they are involved with and are led to reflect on the importance of such subjects for personal and collective decision-making. School students, in turn, by being the target audience for such undergraduate or postgraduate extension activities, can develop an interest in science and a more critical understanding of the scientific endeavour. We argue that the interaction between academic and school students through scientific dissemination can be very fruitful and relevant to the education of both groups.

The University of Minho lists interaction with society among its objectives and projects (Despacho Normativo n.º 61/2008). According to the Minho University School of Sciences (ECUM) website, one of its missions is reinforcing its extensionist feature by carrying out a series of activities to publicise science with the general public and industry, as well as with schools (UMinho, 2023).

This study aimed to identify science dissemination activities addressed to school-age students by the ECUM undergraduate or postgraduate Biology students.

Methodology

The qualitative work presented here results from documentary research (Lüdke & André, 1986), whose data was analysed using an adaptation of Content Analysis (Bardin, 2011).

A search was carried out on all the pages of the "Events", "News", and "Society" tabs of the ECUM website (UMinho, 2023) to identify events or organisations that carried out science communication activities with the extra-academic community, from 2014 to 2023. We also searched ECUM's "Activity Reports" and events described on virtual pages of the departments and centres linked to Biology.

After each event/organisation was found, we searched for their activities. To be considered activities of interest for this study, they had to be organised by the ECUM and express clearly that the target audience was pre-school, primary or secondary school students, with undergraduate or postgraduate students linked to Biology at ECUM as agents, organisers or guides of such activities.

The events' titles and the organisations of interest were put together in a table, with their respective activities giving rise to categories.

Findings and discussion

Twenty-five events/entities of interest were found. The majority (16) aimed at primary and secondary school students, followed by those focussing solely on primary education (5). There were no initiatives aimed solely at pre-school education (table 1). This lack can be explained by the ECUM argument in the "Why Science at UMinho?" tab that the ECUM routine is to organise and promote science dissemination activities with school students (UMinho, 2023), not pre-school children.

Name of the event or entity	Types of activities							*Target school audiences*		
	Lectures, seminars, round tables	**Hands-on activities, games, laboratory practices**	**Presentation/ exhibition of works, stands with models**	**Field trips, guided visits to labora-tories**	**Work-shops**	**Contests, gymkha-nas**	**Showing of videos, documen-taries or movies**	***Pre-school Education***	***Primary Education***	***Secondary Education***
Applied Biology Students Core		■							■	
Best Students at UMinho	■	■		■						■
Biology Department	■	■		■					■	■
Biology and Geology Students Core					■				■	■
Centre for Functional Plant Biology	■	■	■			■	■	■	■	
Centre for the Research and Technology of Agro-Environmental and Biological Sciences			■						■	
Centre of Molecular and Environmental Biology	■	■	■						■	■
Educational and Formative Offer Fair (4U Minho)	■		■		■		■		■	■
European Researchers' Night	■	■	■	■	■	■	■	■	■	■
Learning with Scientists	■	■								■
Meeting "Science and Technology Space Exploration"	■		■						■	■
My Science School	■	■	■	■						■
Open Doors to Science and Technology	■	■	■	■	■			■	■	■
Open Weekend	■	■	■	■			■		■	■
Preparatory Activities to European Researchers' Night	■	■	■	■	■	■		■	■	■
Researchers Return to School	■									■
Science Festival	■	■	■	■	■	■		■	■	■
Science Holidays at the Junior Campus	■	■	■	■				■	■	
Science Through Our Lives	■	■	■		■	■	■	■	■	■
Scientia.com.pt - Experiment@Ciência	■	■	■						■	■
Summer on Campus	■	■	■	■	■				■	■
The Science that I Have at Home		■				■	■		■	■
UMinho Open Doors	■	■	■	■	■					■
Visits by Academics to Schools	■								■	■
Visits Program to the School of Sciences	■	■	■	■				■	■	■

Table 1: events/entities, types of activities and target school audiences.

The categories "Lectures, seminars, round tables" and "Hands-on activities, games, laboratory practices" were the most representative, 21 and 19 times, respectively. Such activities are very relevant since they can discuss the children's and adolescents' imaginations about science and the scientists, their perceptions of scientific knowledge, and the engagement strategies used, making them the protagonists in science dissemination processes (Neves & Massarani, 2008). "Presentation/exhibition of works, stands with models", "Field trips, guided visits to laboratories", and "Workshops" were accounted for 17, 12 and 9 times, respectively.

The events with a higher diversity of activities were: "European Researchers' Night", its "Preparatory Activities", "Science Festival", "Open Weekend", "Open Doors to Science and Technology", "UMinho Open Doors" and "Summer on Campus". This result may be linked to the frequency and dimension of these events, most of which are held annually and attract more and more people.

In addition to these events, some events focus on presenting and discussing the paths and routines of researchers, such as: "Learning with Scientists", "My Science School", "Science Holidays at the Junior Campus", "Researchers Return to School", "Visits by Academics to Schools" and "Visits Program to the School of Sciences". These events can reveal the human nature of the scientific activity to school students, showing that many uncertainties, theories and aspirations cross it.

Finally, stand out the existence of projects aimed explicitly at disseminating science linked to Biology, such as "Science Through Our Lives" and "Scientia.com.pt - Experiment@Ciência".

Conclusions

Biology undergraduate and postgraduate students linked to the ECUM are active in various events/entities and in different types of activities, which promote the dissemination of science mainly to primary and secondary school audiences. Lastly, the intention of this study was not to exhaust the description of all the science communication activities carried out by Biology students linked to the ECUM but rather to get to know those indicated by the ECUM's virtual pages.

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Teachers' long and short experiences of outdoor biology teaching - a way to train new teachers?

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"The construction of a citizen science education on the living in the 21st century: a plurality of actors (teachers, students, researchers, mediators, citizens)"

A first research: the involvement of researchers working on the concept of the living

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1. Research problem and theoretical framework: epistemological and didactic approaches to the concept of the living

G. Canguilhem (1965), physician and philosopher, points out that there is the same relationship between the organism and its environment, as between the parts and the whole within the organism itself. Hence the didactic question of how to teach this complexity, and what place to give to the relationships of living beings with their environment and with each other. The ecosystemic vision of the living world in current school regulations has recently been reinforced (MEN, 2023), particularly in connection with education for the ecological transition. G. Rumelhard (2012), didactician and epistemologist, reinforces this idea of a close link between the living and the environment, speaking of an environment inferred from the living, thus coming closer to the concept of *normativity of the living*[1] proposed by Canguilhem as early as 1943. O. Hamant (2022), a researcher at INRAE, attributes three fundamental aspects to the living world: circularity, the collective behavior of the living world, which ties in with the notion of the interdependence of living beings with each other and with their environment, and robustness, which he distinguishes from performance, and which leads to the resilient character of the living world. This vision would enable us to build a future reconciled with nature, and would help to rebuild a new curricular approach to the concept. Microbiologist M-A Sélosse shows that the concept of organism has reached its limits today, and that we need to "take into account the fact that an animal or plant cannot live without the multiple microorganisms that inhabit it" (Sélosse, 2016, p.80). He thus points to the need for an epistemological break in the Bachelardian sense of the term: to give a central place to interactions, to truly enter an age of the living (Pelluchon & Euvé, 2023). From a philosophical point of view, to know nature is first and foremost to situate oneself in relation to it. C. and R. Larrère (2009) propose a new naturalism, "a good use of nature", a very old idea found in Aristotle. This new naturalism should be ecocentric, based on an objective vision of nature informed by science. It will also involve reconciling global and local ecocentric ethics through political relays that enable us to live in respect for nature and mankind.

These plural and specific approaches converge towards a consensus: that of the importance of an ecosystemic vision of living things, and of the interrelationships between living things. The question now arises in terms of education. C. Fortin (2018), in her analysis of the epistemic status of the living in the new French curriculum, highlights an anthropocentric approach to educational modalities, preventing the construction of an otherness in our relations to other non-human living beings. So what kind of education should we build, taking this consensus into account, and how can we make a scientific education in the living world more relevant to society as a whole ?

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1 Canguilhem G. (1943/1966) (ed. 2009), Le normal et le pathologique, PUF Paris, p. 156: "If biological norms exist, it's because life, being not just a submission to the environment but the institution of its own environment, by the same token sets values not only in the environment but also in the organism itself. This is what we call biological normativity.

Towards citizen science education in the living world

Astolfi (2000), notes the different objectives of science education on very different levels: objectives on a conceptual level, objectives of awakening, academic success and intervention: educating to socially desirable standards, at the same time as giving citizens the means to reason about their choices. We need to reinforce these objectives, which are fully in tune with the current training needs of the 21st century citizen. A.Barthes (2017) points out that the central challenge of "education for" is to train for political citizenship, and ultimately to train autonomous citizens. The authors M-C Bernard et al. reinforce the concept of citizen education, noting that it "pursues the development of the individual as much as his or her action in society" (Bernard et al., dir. C. Simard , 2022, p. 54). In educational research, how to educate for politics is one of the current issues. R. Hétier and N. Wallenhorst (2023) propose the refoundation of political education in the Anthropocene era. F.Kalali (2023) outlines three points for a renewed education in the living world that aims to be relevant to students: firstly, the importance of a normative approach to education based on the activities of scientists, balanced by a second approach, that of the knowledge of individuals in society, and all discussed by those who create curricula. So how can we build this cultural scientific education by developing participatory research involving school players, researchers, mediators and citizens, within an institutional framework? A first approach proposes a reflexive analysis of the role and place that can be played by a first type of actor, namely researchers working on living organisms.

2. Empirical research: an open survey of researchers working on living organisms, who are the first to take part in the project.

An online questionnaire using the LimeSurvey tool was distributed from April to May 2022. The questionnaire was sent out to researchers at three major French public research organizations (CNRS, INRAE, INSERM) and at the UFRs of the universities of Caen and Rouen. It will be stepped up during 2023, until it closes on November 17, 2023, with 130 researchers from all regions of France responding in full to the survey. The architecture of the questionnaire is structured in four parts: Living world, Science and Society, Education, Scientific Mediation.

From a methodological point of view, the work of Barthes and Lange (2018) on the postures of educational researchers in relation to sustainable development, as well as the earlier work of Bonneuil (2006) on biologist researchers in the GMO controversy, has enabled us to show that the study of researchers' postures helps us to better define their commitment and responsibility in the face of educational or societal issues. In this same perspective of establishing postures, the study here, with a statistical and categorical analysis using IRaMuTeQ[2] software, provides us with information on researchers' levels of definition of the living, their involvement in society, their media practices, and the educational approach to their research for a school audience. The knowledge and research produced on the living world can give rise to and contribute to new didactic transpositions for future curricula, and the postures revealed by the study can help us to know to what extent researchers can participate in this. The hypothesis is as follows: the more the researcher conducts his investigations in order to gain a postmodern epistemic vision of the living world, the more he will be led to share his research with society[3] , and the more he will be able to communicate (mediate) and also provide assistance to teachers, and will be closer to educational issues.

The continuation of the study will focus on the interactions between researchers, teachers and students, and will study the forms of knowledge involved, their transposition, and their impact on student learning in a given setting.

[2] IRaMuTeQ: R interface software for Multidimensional Text and Questionnaire Analysis.

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ADAPT Snes

Effects of explicitly communicating the research process on scientific reasoning and epistemic beliefs

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Theoretical background or rationale:
Fostering scientific reasoning competencies (SRC) and epistemic beliefs (EB) is a central goal of science education, as they have been linked to successful science learning and are relevant for participating in public discussions (Engelmann et al., 2016; She et al., 2019). Within international standards and research it was long assumed that implicitly addressing SRC and EB is sufficient for students. However, research results have shown that explicitly addressing scientific thinking and characteristics of nature of science contributes to the development of SRC and EB (Khishfe & Abd-El-Khalick, 2002; Krell et al., 2020). Current research addresses approaches to promote SRC and EB such as *student inquiry* and learning with *contemporary cases* (i. e., cases from the news that are still unsolved). A comparison by Allchin et al. (2014) indicates that both approaches have advantages and disadvantages: *student inquiry* promotes SRC, but may be perceived by students as contrived. *Contemporary cases* promote motivation through the perceived authenticity of the cases, but often cannot address details of the research process because they have not (yet) been published. Explicating the research process is relevant, however, otherwise so-called *black boxing* (Latour & Woolgar, 2013) occurs. By this is meant that the research process remains hidden, similar to a black box, while focusing exclusively on the inputs and outputs.

Key objectives:
Against this background, the main aim of the present project is to develop and test learning videos using authentic cases to convey research findings embedded in the research process. Based on prior findings, it is hypothesized that explicit communication of the research process is beneficial to SRC and EB, but research-based information generated by using videos is currently lacking. Furthermore, relating to the argument that the lack of insights into the research process leads to *black boxing,* the learning videos accompany the entire research process with the camera and interview sequences are used to provide additional insights into consideration processes as well as reflections regarding nature of science aspects. The research questions are: To what extent does explicitly addressing the research process using learning videos with authentic cases promote SRC and EB? What effect do insights into consideration processes and reflections of nature of science aspects have on SRC and EB?

Research design and methodology:
For this study, learning videos are developed in four variants, which differ from each other on the basis of two factors each taking two levels. On the one hand, it is varied whether the research process is addressed *explicitly* or *implicitly*. In the *explicit* condition, knowledge is provided about how to proceed in the research process and why to proceed that way (procedural and conditional knowledge). In the *implicit* condition, the steps in the research process are merely named, but the how and why are not explained. On the other hand, it is varied whether the scientists' communication provides insights into deliberation processes (e.g., sample size trade-offs; selection of materials) and reflections regarding nature of science aspects (e.g., uncertainty, tentativeness, subjectivity of interpretation) or the scientists communicate and explain decisions without giving insights into the thought processes that led to those decisions.
The research procedure involves a pre-post design with intervention in the form of an out-of-school student lab day (Dependent variables [DV]: SRC and EB; independent variables [IV]: Video variants *implicit*/*explicit*, *no/further insights into scientists' thinking*). The assignment of students to the conditions will be done by randomization at the individual level, with students always being assigned to conditions as a dyad (pair). The sample includes secondary school students (Grades 10-13) from SH and NRW, Germany.

Results and Discussion:

All four videos are developed and produced. As exemplary content authentic research projects on the ecology of bats are used. Furthermore, a digital learning environment is developed, in which the videos are by chapters embedded, students complete additional task and the questionnaires. The data collection is expected to be completed by the beginning of 2024. The data is analysed using multi-level analyses. At the conference, insights into videos excerpts, into the digital learning environment and into the results of the analysed data will be presented. In addition, educational implication and implications for further research will be discussed. For example, it will be discussed to what extent the use of the video-based transfer instrument can balance the advantages and disadvantages of *student inquiry* and *contemporary cases*. If the learning videos promote SCR and EB, the described advantages of *student inquiry* and *contemporary cases* would also apply to the use of the videos, but in addition, the disadvantages due to the authenticity of the cases and the possibility of insights into the research process would not apply. This holds the potential for the videos to be another (additional) way to promote SRC and EB in the classroom.

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Investigating pre-service student-teacher understanding about nature of science: implications for teaching

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Theoretical background or rationale:
Schools and teachers play a key role in developing students' science literacy and understanding of the NOS. However, several studies have shown that both teachers and students at different educational levels have naïve understandings of the NOS (Akerson & Hanuscin, 2007; Akerson, Buzzelli, & Donnelly, 2010; Lin & Chan, 2018). The results of various studies show that teachers naively perceive the relationship between theories/laws and observations/conclusions and have misconceptions about sociocultural aspects. Teachers generally acknowledge that scientific knowledge is empirical in nature (Cofre et al., 2019), but Akerson, Buzzelli, and Donnelly (2008) found that most respondents had a simplistic understanding of the existence of a universal scientific method and only half understood that scientists also use creativity and imagination. In addition, findings from a large-scale study of primary and secondary teachers suggest that participants have a fairly good understanding of the preliminary nature of scientific knowledge, but are more likely to have intermediate understanding of sociocultural aspects and creativity/imagination, as well as a naïve understanding of the interrelationships of theories and laws (Karaman, 2018). Research by Mesci and Schwartz (2017) showed that students had the most difficulty understanding the relationship between theory and law and the impact of sociocultural aspects on the development of science. The same aspects proved difficult for primary school teachers (Dogan & Abd - El - Khalick, 2008), as well as the connections between observations and inferences (Cofré et al., 2019). Developing an understanding of the nature of science should begin as early as possible, at least in elementary school, and continue throughout the school years so that students reach the relevant NOS concepts. However, because teachers and their understanding play a key role in developing students' knowledge, it is important to examine their attitudes and levels of understanding. Developing an understanding of the nature of science should begin as early as possible, at least in elementary school, and continue throughout the school years so that students reach the relevant NOS concepts. However, because teachers and their understanding play a key role in developing students' knowledge, it is important to examine their attitudes and levels of understanding.

Key objectives,
The following research questions are put forward:
1. What conceptualisations do pre-service student-teachers hold about the nature of science?
2. How do pre-service student-teachers value teaching the nature of science in school?
3. What differences can be identified between primary and secondary pre-service student- teachers regarding the nature of science?

Research design and methodology,
This study used a purposeful sample of two sets of pre-service student-teachers - (a) students who undertake an integrated bachelor's and master's degree programme to become a primary school teacher and (b) students who undertake a master's degree gymnasium programme to become a secondary level science teacher. The pre-service primary school teachers (hereinafter referred to as *primary teachers*) were 3rd year students (109 students participated). The pre-service gymnasium science teachers (hereinafter *science teachers*) were 2nd year students (134 students). Most of the respondents were female. Data were collected over three years.
An adapted version of an existing questionnaire - Views on Science and Education -VOSE (Chen´s et al., 2006) was used to examine students' perceptions of the nature of science and their attitudes towards incorporating the nature of science into their teaching. The instrument assessed the participants' perceptions of the following NOS aspects: a) tentativeness of scientific knowledge; b) nature of observation; c) scientific methods; d) theories and laws; e) use of imagination; f) validation of scientific knowledge; g) subjectivity and objectivity. Each question was followed by a series of statements (3-9) identifying different positions, the acceptability of which was rated using a 5-point scale. Data were collected and analysed quantitatively. All aspects of the NOS were analysed separately. For this purpose, statements were divided into subcategories and the individual scores of each respondent were calculated in Excel and used in SPSS Statistic 27 for the following up analysis to determine descriptive statistics (mean, standard deviation) and an independent T-test for group comparison.
Opposing stances were sorted into subcategories and scored separately.

Findings,

The data indicates that most pre-service student-teachers perceive tentativeness of scientific knowledge (mean score above 3), but at the same time tend to support the myths most prevalent in science education that there is a single universal scientific method (McComas, 1998). Another common misconception was that scientists did not use imagination, and that science was objective. Respondents believed that theories and laws are discovered and that laws are more certain than theories. Pre-service student-teachers' attitudes towards teaching NOS topics in school were mostly positive. The most positive attitude was towards teaching tentativeness (both groups scored a mean above 4).

A statistically significant difference between the two groups was evident only in the following statements:

a) Primary school pre-service student-teachers were more likely to hold the view that scientific knowledge changes through a cumulative process, while science student-teachers favoured a revolutionary process (significance <.001);

b) The pre-service science teachers were more likely to agree that most scientists follow the universal step by step scientific method, because it guarantees clear, logical and accurate results (significance .004)

Conclusions

The results of the study show that pre-service students-teachers' perceptions about the nature of science are uncertain, sometimes contradictory and often contrary to contemporary views. There were no significant differences among students in the different programs. The conclusion from the results is that student-teachers' perceptions of NOS are not sufficient to teach it in schools. The positive attitudes towards NOS teaching indicates that the situation could be improved by including appropriate topics or subjects in teacher education curricula, i.e., the study shows that teacher education curricula need to be changed

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Scientific creativity in modeling

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Secondary biology teachers' knowledge of epigenetics as a component of their epigenetics PCK

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Theoretical background or rationale

Epigenetics is a new strand of Biology that explains cell differentiation and the interaction between environment and genes. This new area of knowledge has exponentially increased in the last decades promoting new advances in medicine, social sciences (such as learning and behavior) and understanding evolution. Therefore, it is essential that is it taught at school, not only for its scientific and social relevance, but also because teaching epigenetics may help overcome significant challenges in the process of learning genetics, such as genetic determinism (Gericke & Mc Ewen, 2023).

Despite its relevance and the recommendations of scholars, education in the field of epigenetics is in its early stages, and there is an ongoing debate about how to define epigenetic literacy or which ideas should the curricula include. Moreover, epigenetics is not included in biology curricula in most countries. Consequently, it is reasonable to assume that teachers may have gaps in their understanding of epigenetics. Since teacher knowledge is essential to assisting students' learning, teachers' Pedagogical Content Knowledge (PCK) is critical for the introduction of epigenetics in secondary curricula. Every subject within a domain possesses its distinct approach to instruction, taking into account factors such as the topic's inherent characteristics, students' challenges and misconceptions about that subject, educators' instructional objectives for the topic, the subject-specific learning goals in the curriculum, suitable pedagogical techniques designed for the subject, and appropriate assessment strategies tailored to the subject matter (Carlson & Daehler, 2019)

For that reason, it is essential to analyze all these factors that affect the teachers' PCK, in order to contribute to transforming epigenetics for school biology.

Key objectives:

This communication is part of a broader research project, aimed at assessing the change in students' conceptions and teachers' PCK following an educational intervention, considering also their mutual interactions.

In this communication, we just refer to the teachers' PCK and specifically their content knowledge about epigenetics.

Research design and methodology:

We assessed various aspects of Pedagogical Content Knowledge (PCK) using the Refined Consensus Model (Carlson & Daehler, 2019). This model encompasses knowledge related to content, students, curriculum, and instructional strategies. We omitted the assessment component from our evaluation because epigenetics is not part of the biology curriculum in either of the two countries. Assessment occurred via semi-structured interviews were conducted to 16 secondary teachers of Biology, from two different countries (country of authors 1 and 3, country of author 2). Before the interview all the teachers signed informed consent to be recorded.

Teachers' demographic data were registered including the grade(s) they teach, their previous studies and pedagogical training, and for how long they had been teaching biology at secondary or high school.

Concerning their PCK content-knowledge dimension, 4 questions were asked in the pre- interviews:

1. Do you know the term epigenetics? Could you briefly summarize what it consists of?
2. When have you heard about it?
3. Could you create a visual representation with these terms: epigenetics, phenotype, genotype, environment.
4. Why do you think it is important for your students to learn epigenetics?

Interviews were transcribed and analyzed. Open-ended questions, visual representations and the oral explanations teachers made were categorized following an inductive procedure, through a content analysis using a qualitative approach.

Findings:
The analysis of teachers' initial definitions of epigenetics and visual representations showed recognition of the role of epigenetics in environmental influence or gene expression regulation, although the participants were aware of the complexity of the issue and of unresolved questions. Participants used various examples and analogies. However, none of the teachers mentioned molecular epigenetics mechanisms such as DNA methylation or histone modification, suggesting a limited familiarity and shallow knowledge of the domain. Indeed, some teachers seemed to oversimplify the relationships between genotype, phenotype, and epigenetics. For example, some teachers used expressions such as "the environment is the epigenetics" or "epigenetics takes part of everything" to explain (Figure 1).

We also detected some possible misconceptions or unclear concepts: one teacher explained that epigenetics "go first" and then the environment selects the most favorable epigenetic changes (similarly to natural selection of mutations). Another one argued that epigenetics contradicts Lamarckian evolution, and some teachers mentioned that traits acquired through lifestyle changes can be passed down through generations via epigenetics (still a controversial issue). In addition, some teachers are uncertain about the extent of the influence of epigenetics on phenotype.
All of them considered that epigenetics had to be included in the curriculum, arguing that it is needed to make explicit the molecular effect of students' lifestyles and also to pay attention to undermining gene determinism.
Previous training of years of experience in teaching biology did not result in differences in construct-specific PCK.

Conclusions:
The goals of our brief intervention about epigenetics were on one hand, to introduce the concept of epigenetics to the students but also, as it has been suggested, to help biology teachers understand the novel concepts of epigenetics (Mc Ewen, 2022), and to provide them with different teaching strategies for this topic.
Our research showed that, although this content is not present in the curriculum, teachers have a preliminary understanding of this discipline, either due to their previous academic background or their personal interest in the subject. However, this knowledge is often very preliminary and, in most cases, not well-defined, suggesting a need for further clarification about the details of epigenetic processes and a clearer conceptualization of how epigenetics functions as a bridge between genetics and the environment.

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Figure

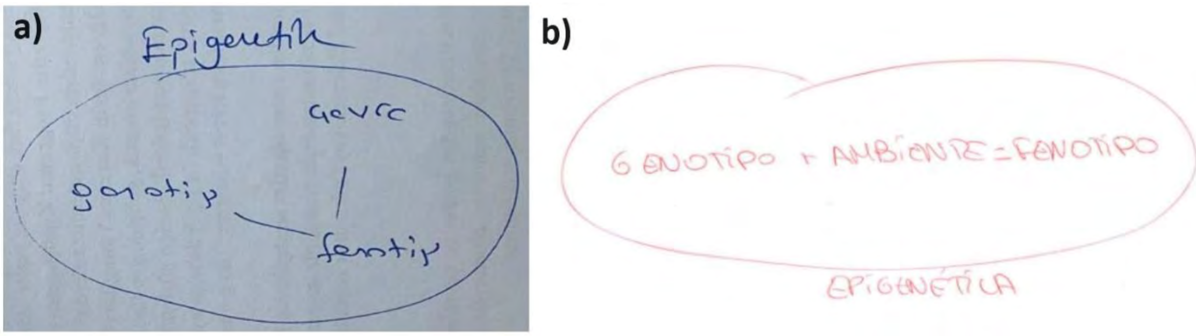

Figure 1: Visual representation of a country2 teacher (a) and country1 teacher. "Ambiente" and "çevre "means environment.

What if the Chimpanzee Belonged to the Genus Homo?

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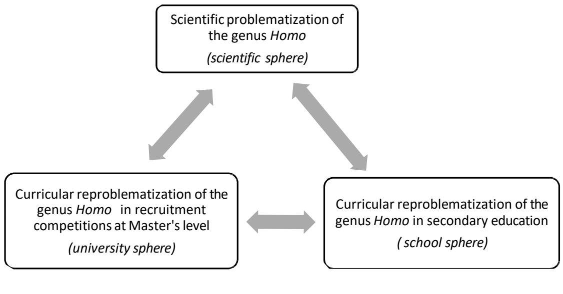
Theorical background
The concept of genus *Homo* is first and foremost a historical construction and the result of theoretical foundations and different explanatory models which bear witness to an epistemological pluralism within the scientific community. Contradictory debate animates this pluralism depending on the classification choices (phenetic, cladistic, biological) with arguments for or against to the inclusion of certain fossils in the genus *Homo* or the inclusion of the Chimpanzee in the genus *Homo*. We would like to emphasize the importance of epistemological pluralism as a structuring element of the nature of science in the sense of *'functional scientific literacy*' proposed by Allchin. Indeed, the genus as a taxonomic rank is not natural entity, but the product of taxonomic rules and different epistemological approaches within the scientific community with some authors including Chimpanzee in genus *Homo*. Consequently, the circulation of conception of genus *Homo* between the scientific sphere, the school teaching sphere and the university teacher training sphere, reflects the process of the re-problematization of the genus *Homo*. It is therefore not only a question of didactic transposition but also a process of deconstruction and reconstruction of genus *Homo* according to teaching or training objectives.

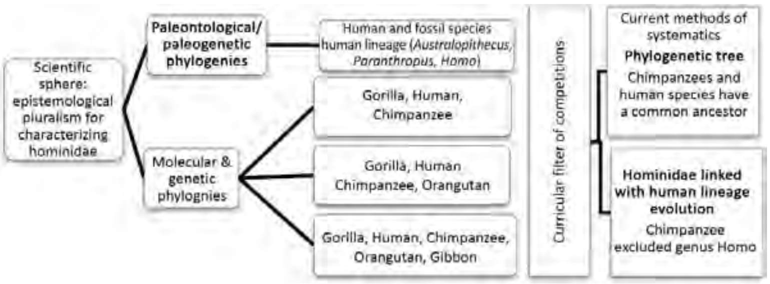
Key Objectives et research question
The circulation of knowledge about genus *Homo* necessarily has a scientific and cultural impact. The choice of favouring one classification over another is not only an internal question for the scientific community, but is also a sociocultural one. For this purpose, it is importance to maintain a pluralistic approach to genus *Homo* in order to integrate the "*functional scientific literaty*" as a field of possibilities within which epistemological and socio-cultural choices are made, such as the possibility of including or not Chimpanzees in genus *Homo*. Thus, the curriculum should not be limited as a tool for programming teaching and learning content; it should also aim to keep epistemological pluralism alive as a driving force for the circulation of knowledge. The knowledge is not necessarily stabilized, as shown by the still open questions of the inclusion of the Chimpanzee in genus *Homo*. The point is not to consider these new proposals as right or wrong, but to understand that they both respond to different epistemological concerns. Questioning the epistemological pluralism of the limits of the genus *Homo* then becomes an issue of training for teachers and an education issue for students. In this context, what knowledge circulation between the fields of scientific research, teacher training and school teaching? What educational or training project do curricula promote in relation to knowledge about genus *Homo*?

Research design and Methodology
These questions that can be answered by analyzing the gaps between scientific problematization and curricular re-problematization. By questioning these gaps, we assume that they are indicative of a curricular reconfiguration of genus *Hom*o, mobilizing or excluding certain epistemological visions depending on the educational or training project. In order to situate the curricular challenges of teaching and learning about genus *Homo* in secondary education and pre-service training (Master's level), indicators de re-problematization are to be sought in the curricula in relation to the scientific problematization genus *Homo*.



The indicators for characterizing the scientific problematization of genus *Homo* are based on the characterization of the genus according to the various scientific classifications which may or may not take the clade and/or the grade, strict monophyly or paraphyly, etc. into account. The indicators will thus make it possible to determine whether the curricular re-problematisations of the limits of genus *Homo* are discussed or imposed.

Findings
In the circulation of knowledge about genus *Homo* between the three spheres (scientific, university training and school education) what conception of genus *Homo* really circulates? Mainly, paleoanthropological knowledge via the fossils. Other classification approaches are neither used nor discuted.



In short, epistemological pluralism within the scientific community to characterize the limits of genus *Homo* is not mentioned in curricula. The curricular re-problematization of genus *Homo*, in middle and high school, follows the guidelines of the pre-service teacher training curricula. Phylogenetic classification is used to highlight the relationship links between the present and fossil species on the basis of genetic, morpho-anatomical, paleontological and paleogenetic data.

Discussion & Conclusion
In conclusion, curricular re-problematizations do not or hardly question the sealing or porosity of genus *Homo* with genus *Pan*. This choice may be also a limiting factor in understanding the epistemological construction of genus *Homo*. The origin of social and cultural behaviour is therefore not integrated into phylogenetic construct, as some researchers advocate because for humans, as for chimpanzees, behaviour and social life present similarities, as well as differences resulting both from a common evolutionary history and from their specific evolution. In a context where the place of the human species in the theory of evolution is not always culturally accepted, it is surprising that the critical dimension relating to the limits of genus *Homo* is not the subject of training. However, a pluralist approach would avoid a form of essentialization of genus *Homo*. As a result, "*functional scientific literacy* " is not taken into account in curricula, at the risk of opening the door to a pseudo-rationalization of prejudices about the human exception by reinforcing an anthropocentric view of genus *Homo*.
Consequently, we propose that curricular re-problematization should not be limited to a "monstration" of genus Homo by exhibiting anatomical or molecular data, but should also be organized around epistemological pluralism in a critical approach that takes into account the question of our relationship of otherness to other great apes.

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Environmental Education

Factors influencing primary school children's knowledge about fauna from local and exotic biomes

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Theoretical background or rationale

One of the most alarming indicators of the current global crisis is the decline in biodiversity, primarily attributed to the loss of species' habitats (Jaureguiberry et al., 2022). In the framework of environmental education, a proper biodiversity education that is sensitive to the local ecological context can be a key strategy supporting the necessary behavioural changes to address the ongoing biodiversity crisis (Reid et al., 2021).

Some works diagnosing biodiversity knowledge by picture identification or free-listings have revealed that people from westernized countries have a limited awareness of native species (Almeida et al., 2018; BLINDED, 2022). However, results of works based on species listing in relation to their biome are scarce and results are inconsistent (e.g., Yli-Panula & Matikainen, 2014).

Given that children face personal and political decision-making processes regarding biodiversity issues in current and future contexts, it is imperative to diagnose their biodiversity literacy and the factors shaping it. This assessment is essential for formulating effective educational strategies, especially for promoting native species conservation and the habitats containing them.

Key objectives:

The main goal of this study is to assess northern Spain children's knowledge about fauna from local and exotic biomes and which factors influence it (gender, school type, hometown size, educational level, interest in nature, interest in animals).

Research design and methodology:

The study was conducted in BLINDED. The potential terrestrial biome in the area is the temperate mixed forest. Participants included 949 students aged 6 to 12 years old attending all the levels of Primary Education.

Students were provided a paper composed of different parts. In the first one, a photograph of a local temperate mixed forest appeared and children were asked to write down as many animals as they knew that lived there. The second task was almost identical, but the photograph appearing was a picture from the African savannah. Finally, children had to rate their interest in nature and in animals.

For data analysis, the number of animals mentioned by children for each biome was counted. Subsequently, the number of correct answers -the number of wild animals from the lists properly corresponding to each biome- was defined and quantified. Afterwards, the taxonomic resolution level of each of these correct animals was determined and scored as in BLINDED (2023). Next, children's knowledge on local and exotic fauna was assessed by summing up the scores obtained by wild animals properly belonging to each biome, which resulted in a Biodiversity Accuracy Index (BAI). Finally, the links between students' knowledge about fauna
(i.e. BAI) and the possible factors affecting it were investigated by Generalized Linear Mixed Models.

Findings:

Children, on average, listed more animals for the African savannah picture than for the native temperate forest (Table 1). In addition, the number of animals correctly belonging to the biome in the photo and the BAI score were higher for the case of the exotic biome in comparison to the local one.

Table 1

Mean listed animals and Biodiversity Accuracy Index (BAI) for the local temperate forest and the exotic African savannah biomes

Biome	Total	Native	BAI
Temperate forest	5.0	3.6	1.47
African savannah	5.7	4.6	2.66

Both interest in nature and in animals were significantly and positively related to a higher BAI score for the two biomes (Table 2). However, students' knowledge about local fauna was also significantly influenced by their hometown size (being students from smallest villages the ones achieving highest BAI scores); whereas knowledge about exotic fauna was significantly affected by students' gender (boys reflecting higher knowledge than girls) and their educational level (students attending higher grades scoring a higher BAI).

Table 2
Factors affecting students' knowledge (BAI) about native and exotic fauna

Biome	*Factor effect*	F value	p>F
Temperate forest			
	Hometown Size (-)***	4.96	<.001
	Interest in Nature (+)*	3.97	.046
	Interest in Animals (+)**	7.83	.005
African savannah			
	Gender (M>F)**	5.97	.003
	Educational level (+)***	5.52	<.001
	Interest in Nature (+)***	10.94	.001
	Interest in Animals (+)***	13.87	<.001

Conclusions:
Students from the present work reflect a higher species knowledge from the exotic African savannah, than from the local native biome. This result can be a consequence of the overall decline in people's contact with their surrounding nature (Soga et al., 2016), having other sources a major influence on their biodiversity knowledge.
Results also suggest that students do not receive enough information about local fauna from school, since educational level is only linked to higher knowledge about savannah animals. In fact, hometown size is the only different factor significantly affecting students' knowledge about native animals, as previously observed in other works (e.g., BLINDED, 2022; BLINDED, 2023). Regarding exotic fauna, the positive effect of the educational level on students' knowledge can suggest that, with age, students receive more information about exotic fauna from different sources (TV, cinema, internet…), and that boys seem to be more interested in this particular fauna than girls are.
Briefly, it can be deduced that contact with nature when students live in rural areas may positively influence their knowledge about native fauna, and hence, nature place-based education strategies can be suitable approaches to address biodiversity education. On the other hand, the real causes of the increase in knowledge about exotic fauna with age must be further researched.

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Animal talk amongst biology a-level Students: beginning with a sense of self to understand nonhuman animals

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Attitudes' role in learning about the environment

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Theoretical background or rationale
In a typical classroom lesson, students face the same learning opportunities. However, learning outcomes are heterogeneous, while knowledge about the environment is fundamental to act upon; besides further contributing factors (see, e.g., Sirin, 2005), people need knowledge about the environment and environmentally friendly behaviors to continuously engage pro- environmentally. The literature points to attitude's supportive effect on knowledge levels and for pro-environmental engagement (e.g., Henn et al., 2019) and casts light on two perspectives: *Attitude toward nature* (see Brügger et al., 2011) resonates with nature appreciation. It implies people do something for the environment because they want to, e.g., enjoy beautiful nature or pristine landscapes. Hence, the environment is worth protecting. *Environmental attitude* shows in people's commitment to nature preservation as an inherent motivational force (Authors a). The literature is yet unspecific about those attitudes' relationship and their link to (classroom) learning, which would help derive educational recommendations.

Key objectives:
The main goal was to investigate attitude toward nature and environmental attitude's role in learning about the environment (i.e., knowledge about facts and behavioral choices), given that students face similar learning opportunities but do not engage equally. We were thus interested in whether attitudes help people acquire and use knowledge. In this regard, we expected attitude toward nature and environmental attitude to work synergistically as inherent motivators that help classroom engagement, thus learning, and, ultimately, persistent pro-environmental engagement. We hypothesized their roles in Figure 1. Then, we analyzed gender differences and looked at the attitudes' trajectory throughout adolescence for curricular recommendations.

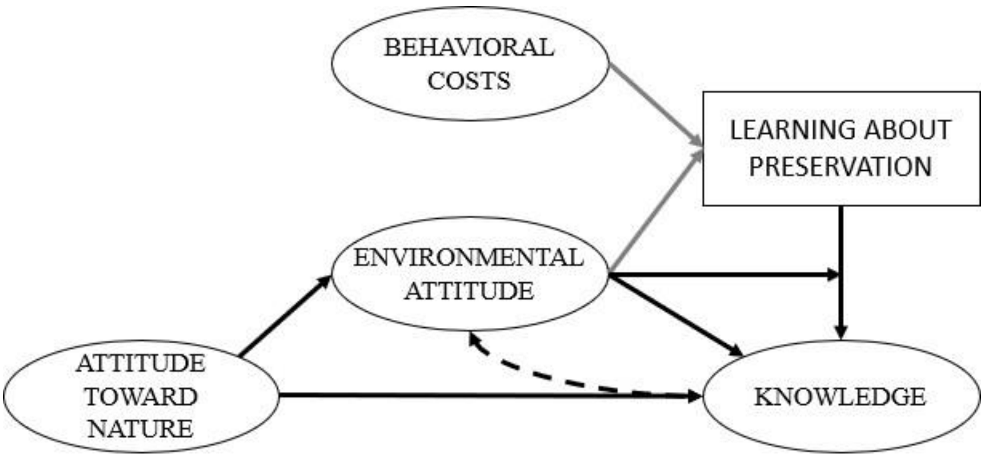

Figure 1: Environmental attitude's and attitude toward nature's role in learning about environmental protection and preservation. Attitude toward nature positively affects knowledge gain and retention, while environmental attitude is a mediator to support knowledge acquisition.
In this regard, environmental attitude affects whether people take learning opportunities and how rigorously they learn, which shows in the positive correlation we typically find between attitude and knowledge. Costs – within the Campbell Paradigm – are all obstacles (time costs, resources, etc.) preventing actions (for further information on the Campbell Paradigm, see Kaiser et al., 2010).

Research design and methodology:
In a quantitative study approach, 1,486 students (M_{age} = 15.25, *SD* = 3.2; 48.5% [*n* = 721] females, 46.2% [*n* = 686] males, 5.3% [*n* = 79] provided no information on gender) answered questionnaires that contained environmental knowledge (system, action, and effectiveness knowledge, see Frick et al., 2004) in a multiple-choice format, environmental attitude (Authors a), attitude toward nature (see Brügger et al., 2011) on five-point frequency scales, and little personal information such as gender and age. The dichotomous Rasch model was used for either scale. Calibrations revealed good fit indices and thus a basis for further analyses (Bond & Fox, 2007):

- Knowledge (n_{items} = 25): *rel*. = 0.70, logits = −2.35-3.61 (*M* = 0.53, *SD* = 0.89), mean square values weighted by the item variance (MS) = 0.86-1.25
- Environmental attitude (n_{items} = 52): *rel*. = 0.78, logits = −4.02-4.0 (*M* = −0.48, *SD* = 0.91), MS = 0.84-1.20
- Attitude toward nature (n_{items} = 48): *rel*. = 0.87, logits = −4.28-3.12 (*M* = −0.63, *SD* = 1.05), MS = 0.74-1.30

Findings:
Environmental attitude affected whether students took learning opportunities and how rigorously they learned (β = 0.239). At the same time, there was an inverse relationship of pre- test knowledge (β = −0.315) on knowledge gains: $F(2, 380) = 21.18$, $p < 0.001$, R = 0.317, R^2 = 0.101. Attitude toward nature also supported knowledge acquisition and retention ($F[3, 378]$ = 9.32, $p < .001$, $R^2 = .069$). However, environmental attitude acted as a full mediator in the relationship between attitude toward nature and long-term knowledge scores: 0.1829, 95% CI (0.1224, 0.2487), as hypothesized in Figure 1.
There were no gender differences in the measurement of environmental attitude. However, there were gender differences in the attitude toward nature measurements, such as that items about nature contemplation or strong emotions were more embraced by females, while males embraced more strongly items about outdoor activity and nature interest (see Figure 2). Nevertheless, those items were balanced and differed moderately, so neither gender was discriminated against by the measurement.
The trajectory of environmental attitude throughout adolescence was relatively stable. On the other hand, attitude toward nature levels were fairly low in 11 to 12-year-olds and successively increased until adulthood, with a slight peak in 14-year-olds. As such, a cubic regression explained the trajectory throughout adolescence better than a linear or quadratic one: $F(3, 1466)$ = 29.069, $p < .001$, $R^2 = .056$.

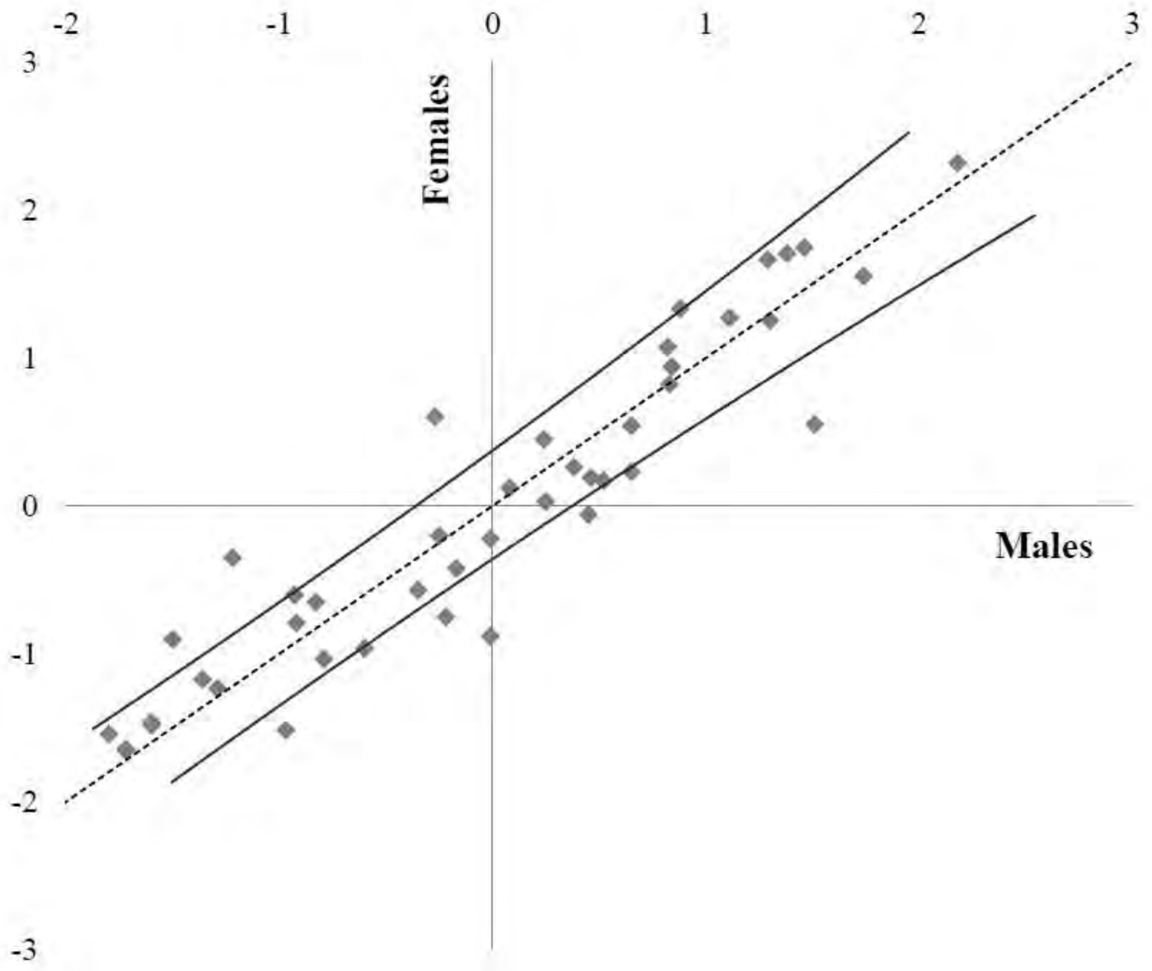

Figure 2: Item Differentiating Test for the attitude toward nature measurement to test gender differences. Items within the effective 95 CI are identical for either gender, while there are gender differences for all items beyond the solid lines.

Conclusions:

Attitude toward nature and environmental attitude support learning about the environment and environmentally friendly behaviors, thus setting the ground for pro-environmental engagement. While attitude toward nature precedes, environmental attitude acts as a mediator and affects the likelihood that learning opportunities are taken and how rigorously students learn, which shows in the amount of knowledge students gain and retain within a classroom setting. On top of teaching knowledge about the environment and pro-environmental behaviors, it is essential to strengthen attitude toward nature (i.e., nature appreciation) and environmental attitude (i.e., personal commitment to nature preservation). Teaching nature appreciation appears particularly important in early adolescence to counteract low levels that slowly increase throughout youth. Further studies could investigate outdoor program's or childhood experience's potential to strengthen both and, in particular, attitude toward nature.

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Promoting experimentation and modelling competencies

In-Service Biology Teachers' PCK on Promoting Students' Experimentation Competencies and Its Development through a Professional Development Program

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Theoretical Background

Developing scientific thinking competencies is considered an important goal of biology education (e.g., KMK, 2020). Thus, the literature recommends focusing less on content knowledge and more on engaging students in scientific inquiry, e.g., in the form of experimentation, and explicitly reflecting about the procedural and epistemic knowledge involved (Krell et al., 2022). However, studies suggest that an explicit approach to promote experimentation competencies seems to be little used in classroom practice (e.g., Vorholzer et al., 2022).

Teachers' pedagogical content knowledge (PCK) has a great influence on the quality of classroom practice (Blömeke et al., 2022). Accordingly, it is reasonable to assume that a low PCK of biology teachers to promote experimentation competencies could be one reason for the lack of explicit approaches to develop experimentation competencies of students (among other factors such as limited resources or time).

Key Objectives

We developed an in-service professional development (PD) program with a focus on promoting students' experimentation competencies. Furthermore, we used an adapted version of the Content Representation instrument (CoRe; Loughran et al., 2001) to investigate, first, how the biology teachers' PCK was constituted before participation in the PD program and, second, the extent to which teachers' PCK has developed as a result of participating in the PD program. Therefore, the research questions (RQ) are as follows:

RQ1: How can biology teachers' PCK on promoting experimentation competencies be characterised?

RQ2: To what extent does biology teachers' PCK on promoting experimentation competencies develop as a result of participating in a PD program?

Research Design

A number of *N*=24* in-service biology teachers took part in the pre-test. After participating in the PD program, a number of *N*=12* in-service biology teachers took part in the post-test (*data collection in progress). All teachers were teaching at secondary schools in Germany. The PD program aimed to foster in-service biology teachers' professional competencies to promote students' experimentation competencies (see AUTHORS, 2023).

To measure teachers' PCK on promoting students' experimentation competencies, we adapted the existing CoRe (Loughran et al., 2001) by adding introductory text. Teachers were asked to respond to eight open-ended questions and, thereby, described their ideas of teaching a particular topic. In our adapted CoRe, biology teachers were asked to formulate their teaching ideas for promoting scientific thinking competencies through experimentation with photosynthesis as an exemplary context.

A qualitative content analysis (Schreier, 2012) was conducted using the five components of teachers' PCK from the Pentagon model (Park & Oliver, 2008) as deductively derived categories, which are orientations to teaching science (OTS), knowledge of instructional strategies and representations for teaching science (KISR), knowledge of students' understanding in science (KSU), knowledge of science curriculum (KSC), and knowledge of assessment of science learning (KAs). It was coded whether teachers' responses referred to content knowledge (ck), procedural knowledge (pk), or epistemic knowledge (ek). For KISR, we also decided whether teachers described an implicit or explicit approach. The intercoder agreements of two independent coders was κ=.86.

Findings

The findings show that prior to the PD program, teachers particularly referred to the teaching of content knowledge as an orientation (e.g., learning the products of photosynthesis; OTS). Furthermore, most instructional strategies described were explicitly directed toward learning content knowledge (e.g., using an experiment to show the products of photosynthesis; KISR). Similarly, teachers' expectations of students' understanding were mainly related to content knowledge (e.g., plants need water for photosynthesis; KSU). In the responses, barely any codes were assigned for KSC and KAs.

Looking at the teachers who participated in the PD program (Table 1), it appears that these teachers refer more often to the teaching of procedural and epistemic knowledge in the post-test (e.g., learning how to design an experiment; OTS). Furthermore, the instructional strategies described were more often explicitly directed toward learning procedural knowledge (e.g., discussions to justify the design of a planned experiment; KISR). In addition, teachers' expectations of students' understanding were equally related to content knowledge as well as to procedural knowledge in the post-test (e.g., confuse test and control variables; KSU).

Table 1
Absolute numbers of coded segments in the CoRe of the teachers who participated in the pre-test and post-test (N=12)

Category	Pretest	Posttest
OTS – ck	61	18
OTS – pk	4	28
OTS – ek	1	5
KISR – ck – *implicit*	0	0
KISR – ck – *explicit*	16	10
KISR – pk – *implicit*	11	15
KISR – pk – *explicit*	4	17
KISR – ek – *implicit*	0	1
KISR – ek – *explicit*	0	0
KSU – ck	35	25
KSU – pk	6	23
KSU – ek	0	0
KSC – ck	1	0
KSC – pk	2	0
KSC – ek	0	0
KAs – ck	9	5
KAs – pk	0	3
KAs – ek	0	0

Note. The numbers of teachers who did not participate in the PD program and/or the post-test are not included in this table.

Conclusion
Analysis of biology teachers' PCK shows that they focus strongly on teaching content knowledge, even when asked how they would promote experimentation competencies. This supports the assumption that a low PCK of teachers could be a reason for the lack of explicit approaches to develop experimentation competencies of students. However, the results also show that the teachers' PCK on promoting students' experimentation competencies can be developed through participation in a PD program.

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Relation between metamodeling knowledge and modeling practices depending on content knowledge

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Theoretical background

Modeling is the process of generating new knowledge through the construction and application of models (Nielsen & Nielsen, 2021). Modeling practices refer to actions that are performed during this process and include *constructing models*, *using models to predict*, *testing models*, and *revising models* (Schwarz et al., 2022). As modeling is an authentic scientific endeavour, it is important that learners are able to engage in these modeling practices (Schwarz et al. 2022). However, learners struggle to do so (Cheng et al., 2021; Göhner et al., 2022), raising the question of what is needed to engage in modeling practices. Scholars suggest that prior content knowledge (CK) and metamodeling knowledge (MMK) foster engagement in modeling practices (Nielsen & Nielsen, 2021; Schwarz et al., 2022).

While CK refers to knowledge about “appropriate domain-specific concepts” (Kind & Osborne, 2017, p. 10), MMK is domain-general and includes knowledge about the practices being involved in the modeling process (Nielsen & Nielsen, 2021).

Recent studies did not find a correlation between MMK and the ability to engage in modeling practices (e.g., Cheng et al., 2021; Göhner et al., 2022). A possible reason for that could be that participants had little CK about the modeled phenomena. However, CK was not controlled in related studies. This is important since other studies found that CK about the phenomenon fosters the ability to engage in modeling practices (e.g., Bennett et al., 2020; Ruppert et al., 2017). However, these studies did not explicitly assess MMK.

Key objectives

It remains unclear how MMK is related to learners' ability to engage in modeling practices especially, depending on their CK. Aiming for clarification, we examine the following research question:
To what extent are MMK and the ability to engage in modeling practices related, depending on modelers’ CK about the phenomenon they model?

Design and Methodology

Data collection is ongoing to achieve a sample of 100 participants, currently at 32. Similar to Göhner et al. (2022), pre-service science teachers are participating in this study.

Participants' MMK is assessed through a diagram task (Engelschalt et al., 2023), in which they are asked to create a process diagram representing their conception of the modeling process. Using a coding scheme, two raters co-analyzed how many practices were addressed in participants’ solutions for the diagram task as a measure of their MMK (table 1).

Table 1: Coding scheme for scoring participants’ MMK (adapted from Engelschalt et al., 2023).

Practice	**Scoring** *Participants received a point if their diagrams displayed…*
Constructing models	… that models are developed based on data about the phenomenon.
Using models to predict	… that models are used to derive assumptions about the future behaviour of the phenomenon.
Evaluating models	… that models or model-derived hypothesis are tested with data.
Revising models	… that models are refined if they are contradicted by data.

Participants’ ability to engage in modeling practices are assessed through two modeling tasks, which are instructed similarly: After the presentation of a phenomenon including data about it, participants respond to four open-ended instructions. Using a coding scheme, two raters co- analyzed how many practices were addressed in participants’ responses to the modeling task instructions as a measure of their ability to engage in modeling practices (table 2).

Table 2: Coding scheme for scoring participants’ ability to engage in modeling practices

Practice	Related modeling task instruction	Scoring *Participants received a point if they…*
Constructing models	Construct a model to explain the described phenomenon.	… included the provided data in their models to explain the phenomenon.
Using models to predict	Use your model to derive a concrete prediction about the future behaviour of the phenomenon.	… formulated a concrete assumption about the phenomenon extending the information in their constructed models.
Evaluating models	Describe a strategy for examining whether your model can actually explain the phenomenon.	… described a strategy for evaluating their models or model-derived hypotheses, e.g., a concrete experiment.
Revising models	Outline how you would continue in your modeling based on presented data. (Participants received additional data that contradicted their models before this instruction)	… outlined how to revise their models to fit the presented data.

We conducted modeling tasks on two different phenomena: a male clownfish (CF) changing its sex and a person with a reddened face (RF). Participants modeled both phenomena in a randomized order. Controlling the variation of participants' CK between the modeling tasks, we measured their self-reported CK using three items on a 7-point rating scale. For the CF task, participants reported having used little CK (M= 3.12). In contrast for the RF, they reported having used much CK (M= 6.11).

Findings

Participants engaged in fewer modeling practices during their work on the CF than the RF task (M_{CF}=1.65 to M_{RF}=2.42, p<.05). This matches previous findings indicating that CK about the modeled phenomenon fosters the ability to engage in modeling practices (Ruppert et al., 2017). We found a moderate correlation between the number of practices addressed in the MMK diagram task and the number of practices participants engaged in during the CF task (r=.43, p<.05). In contrast, no correlation was found for the RF task (r=.15, p=.63). A possible explanation for this result could be that, with high CK available for the RF, engagement in modeling practices is nearly intuitive. Lacking CK, participants might have needed sophisticated MMK to be able to engage in modeling practices which could explain the moderate correlation between MMK and the ability to engage in modeling practices for the CF task.

Conclusions

Our findings extend previous research (e.g., from Göhner et al., 2022) by suggesting that MMK is connected with the ability to engage in modeling practices when CK about a phenomenon is not available. For designing learning environments, this might indicate that learners with limited MMK may benefit from modeling phenomena they have CK about, while learners with advanced MMK are able to model phenomena they have little CK about. These conclusions need to be substantiated by further results from our larger sample.
Additionally, we will interview 18 participants to reflect on their modeling processes and the knowledge they relied on. This might provide additional insights into how MMK guides engagement in modeling practices.

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Investigating the relationships between the dimensions of modeling competence

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Theoretical background or rationale

Models play an essential role in science as tools for representation and for exploring and predicting phenomena. Accordingly, modeling competence is defined as one goal of science education. To help their students develop modeling competence, prospective science teachers (PSTs) must acquire comprehensive modeling skills during their professional development (Chiu & Lin, 2019).

Modeling competence can be divided into three dimensions (Chiu & Lin, 2019; Nicolaou & Constantinou, 2014):

(1) modeling metaknowledge [consisting of metamodeling knowledge (MKM) and metacognitive knowledge of the modeling process (MKP)]

(2) modeling practices (MPRA)

(3) modeling product (MPRO). Krüger and Upmeier zu Belzen (2021) divide MKM into five aspects (see Table 1) with three levels each, ranging from a naive to a comprehensive understanding of models. Studies show that teachers often have limited MKM, and models are predominantly used as representations in school (e.g., Nielsen & Nielsen, 2021).

MKP includes knowledge about the components of the modeling process (see Table 3) and the sequence of individual steps (Nicolaou & Constantinou, 2014).

Although several studies have investigated these dimensions, their relationships have been studied less (Chiu & Lin, 2019). However, to diagnose individual aspects of the dimensions and to foster modeling competence comprehensively, this research gap needs to be addressed. One of the few existing studies investigating the relationship between the individual dimensions is Engelschalt et al. (2023). The authors found a positive relationship between MKM and MKP, especially for the MKM-aspect purpose of models and the MKP-component predict with the model. Participants who included this component in their drawn diagrams of the modeling process also had an overall higher level of MKM. To generalize these findings, good scientific practice requires that they be verified in replication studies (Yong, 2012).

Key objectives:

One of the subordinate research questions of our study is: *What is the relationship between PSTs' MKM and MKP?*

By addressing this question, this study aims to provide insights into the relationship between the dimensions of modeling competence and the individual dimensions (Chiu & Lin, 2019). Furthermore, this study aims to replicate and establish the existing findings of Engelschalt et al. (2023).

Research design and methodology:

Our study is conducted in a mixed-method quasi-experimental design with PST from the German Bachelor's and Master's programs, using established quantitative and qualitative tools to assess MKM and MKP. First, the participants answered an online questionnaire with five open-ended questions, each addressing one aspect of MKM (Krell & Krüger, 2016). Additionally, they do a diagram task to assess their MKP (Engelschalt et al., 2023). The responses regarding MKM were qualitatively analyzed by two raters (Cohen's κ=.63) using an existing coding scheme (Krell & Krüger, 2016). Two raters also analyzed the diagrams using a coding scheme adapted from Engelschalt et al. (2023), including a component and a structure score (κ=.80 component score, κ=.87 structure score). The component score describes whether the components can be found in the diagrams, and the structure score (level 1-3) describes the extent to which the participants understand the modeling process as a cyclic, iterative process.

Findings:

So far, *N*=62 PSTs from the German Bachelor's- and Master's programs have completed the questionnaire. Two raters have already coded 41 responses to the open-ended-questions and 31 to the diagram task. Data collection is still ongoing.

The findings show for MKM that most responses can be assigned to level 2 (Tab. 1). It is noticeable that responses to the aspect *Purpose of models* are predominantly in level 1. The diagrams also could predominantly be assigned to level 2 of the MKP structure score (Tab. 2).

Additionally, the examined diagrams show the MKP component *Predict with the model* the least; this component could only be identified in five diagrams (Tab. 3). Hence, the participants seem to perceive models more as representations and less as tools to explore and predict phenomena. These findings are consistent with results from previous studies (e.g., Krell & Krüger, 2016).

In contrast to the findings of Engelschalt et al. (2023), we found no significant correlation between the participants' MKM and MKP (r=-.12, p=.51). Therefore, our results also support the view of Nicolaou and Constantinou (2014), who suggest that the individual dimensions of modeling competence and in particular the classification of MKP and MKM as separate constructs should be reviewed and reconsidered.

Table 1

Distribution of response levels regarding the five aspects of MKM open-ended questionnaire (N=41)

	n responses level I	n responses level 2	n responses level 3	NA[1]
Aspect	**MKM (n=41)**			
Nature of models	7	31	/	3
Multiple models	2	20	16	3
Purpose of models	26	14	1	/
Testing models	11	14	6	10
Changing models	1	37	1	2

Missing values due to questions not answered or the answer could not be rated

Table 2

Classification of the diagrams according to the structure score level for MKP diagram task (N=31)

Structure score	level I	level II	level III
	9	16	6

Table 3

Number of named components for MKP diagram task (N=31)

Components	Develop evidence-based models	Predict with the model	Test the model with data	Revise the model
	27	5	14	23

Conclusions:

The initial and not yet completed analyses show for MKM and MKP that participants predominantly perceive models as tools for representation.

Due to the small sample size analyzed so far, no significant correlation has been found between participants' MKM and MKP. Therefore, the relationship between MKM and MKP cannot be clearly defined at this point. Further analyses are necessary to substantiate the results and to identify additional relationships between the individual aspects of MKM and MKP. Findings based on additional data analysis, including sample responses and diagrams from the questionnaire, can be reported at the conference.

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Metrological concepts in biology courses in higher education

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Theoretical background or rationale

Measurements are central in scientific research and development activities. Unfortunately the concepts of metrology - the science of measurement - are obscure to most biology researchers (Houle and al., 2011). However, adjustments should be done to the subjects studied in biology and their features (Montevil, 2019). Lange (2000) pinpoints a key question about meaningfulness and reliability of a measurement. This issue is linked to the nature of science and to the representational measurement theory which discriminates against the different kinds of attributes, or scales type of measurement (Houle and al., 2011; Lange, 2000). Therefore, developing a culture of concepts of metrology might improve future researchers' skills but also students' confidence in scientific results. Regarding biology education, this reflection is central to teach how a discrepancy between a measurement and its meaning could lead students to mistakes in the analysis and the interpretation of data. Actually, the metrology issue is introduced in the high school physics and chemistry curricula and the French national standards for bachelor's degrees of experimental sciences (2015) mention related skills such as "identifying error sources to calculate uncertainties for an experimental result". Despite this, it appears that few biology course syllabi include metrology concepts.

Some science education studies dealt with the teaching and learning of quantities and measurement concepts at primary, secondary school and university level in physics and mathematics (Caussarieu & Tiberghien, 2015, Auteur 2, amongst others). Only one comparative research dealing with biology education was conducted by Fondère et al. (1998) about specific tasks related to measurement during practical work sessions in biology, chemistry, and physics. The authors noticed some characteristics of the disciplines and underlined the significance of a decision regarding the quality of measurement values. While this study deals with uncertainties in measuring systems, a broader issue based on the teaching of metrology is not discussed.

As few researches deal with this issue, we lead an exploratory study to investigate the place of measurement education in the first years of university degree of biology in France. Thus, we look at the concepts and methods dedicated to metrology formulated in exercise and practical session documents. We also explore, through interviews, teachers point of views about the role of measurement for research in biology and its position in education.

Research design and methodology:

Firstly, biology and physic course materials (exercise and practical sessions) of first year university degree of biology provided to students are collected then analysed through a grid set up on the work of Fondère and al. (1998) and on the main axes of metrology (Perdijon, 2012). Concepts and methods of measurements are characterised through five rubrics: type of data and measurement; implementation; management; results and values processing; interpretation. Secondly, we interview four biology teachers implied in the analysed biology courses. The interview's guide is constructed to explore the intended purposes dealing with measurement in the teaching sessions as well as their conceptions (as scientist) of the measurement in their research field. Finally, to investigate if our results are reflecting a trend of most university degrees, we are developing a questionnaire that will be addressed to head teachers of biology degrees across France.

Findings:

Our analyse of biology course materials reveals that students carry out some measurements during practical work sessions and analyse quantitative or qualitative data by processing and interpreting them in exercise sessions. However, measurement is not an explicit goal of learning: data are mainly descriptive, measurement implementation paragraphs are mostly informative or descriptive and with rare instances of critical examination. Furthermore, major metrological concepts and methods are notably absent: there is no item dealing with measurement management and decision-making about confidence in values – the

quality of data (reliability, validity) is never questioned –, no item questioning the compliance of the model and items about reflexive feedback on the measurement protocol are rare. The variability (caused by measurement or by biological process) is largely unaddressed.
All the interviewed teachers pinpoint the importance of understanding scales, orders of magnitude, and the fundamental characteristics of certain experimental techniques in their teaching sessions. The mentioned data are mainly quantitative (or countable). The scale diversity seems to be influenced by the biological speciality (animal, plant or cell biology, genetics). Nonetheless, they don't spontaneously address issues of measurement reliability and validity. These observations are consistent with their measurement definition linked to a quantification and a technique of measurement. Despite their unanimous recognition of the importance of measurements in biology research, measurement education is mostly delegated to physics and mathematics lectures without questioning the specificity of measuring biological features.

Conclusions:
These results enlighten our vision of the place of measurement in biology education in the first years of university. They highlight certain deficiencies, mainly about the quality of data. In the near futures, we expect for the presentation to enrich our findings with the analyses of physics courses materials and draw a wider overview of measurement education in French biology degree with the result of our questionnaire. Beyond this exploratory study, a specific measurement education included in those sessions could be design to address this issue in collaboration with the teachers.

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Opportunities to address socioscientific issue

Context matters when assessing science civic engagement

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Introduction

Science educators are increasingly concerned with fostering *science civic engagement* (SCE), or apply science skills for the betterment of society (Rudolph & Horibe, 2016; Sass et al., 2020). Science education using socioscientific issues (SSI) has been shown to be effective for developing SCE competencies. Successfully developing students' SCE through classroom activities is reliant on students' ability to use skills learned in one context and apply them to another, and apply classroom learning to real-world experiences. This idea is incorporated into the concept of SCE (Alam et al., 2023), which includes four subconstructs measured by the Predictors of Science Civic Engagement (PSCE) survey (Table 1).

Predictors of Scientific Civic Engagement survey (PSCE)

The relevant course taken ("Biology," "Engineering," or "Science Literacy" is piped into survey items that contains the word SUBJECT.

A community is defined as a group of people who interact and share a common sense of identity, social values, attitudes, interests, or goals (e.g., if you are a resident of New York City then you might identify with the community of "New Yorkers" and/or if you identify as Hispanic then you are a member of the Hispanic community)."

What is one community with which you strongly identify? Your responses to the survey will be based on this.

Subscales:	Students choose: COMPLETELY AGREE – AGREE – SOMEWHAT AGREE – SOMEWHAT DISAGREE – DISAGREE – COMPLETELY DISAGREE – I DON'T KNOW
Civic self-efficacy (CE)	I am confident that I can contribute to improving life in my community using my SUBJECT skills.
Civic Action (CA)	I plan to help with a community event or organization using my SUBJECT skills.
Civic Knowledge (CK)	I can think of ways to apply my SUBJECT skills to help my community.
Civic Value (CV)	I have a responsibility to help solve my community's problems using my SUBJECT skills.

Table 1: Examples of items in the PSCE survey

Transfer theory (Haskell, 2000) explains how learners use ideas and competencies, experienced in one context to engage new contexts with different features. The context in which knowledge is introduced plays an important role in the ability to transfer that knowledge and is important for knowledge retention and application (Klassen, 2006).

However, learning may be so tightly connected to context that it doesn't readily transfer to another context (Bransford et al., 2000). And not all contexts are equivalent, as students' existing familiarity or stake in a particular SSI or learning context may affect their ability to successfully transfer reasoning skills (Romine et al., 2020).

In general, creating competency-focused instruments is challenging because of the dissonance between the context-specificity of competency learning and the need for pragmatic broad assessments that are context-general. The advantage of PSCE is that it can be flexibly contextualized for both the competency (knowledge and skills associated with a particular course) and either an issue or setting for action (a specific community).

Objectives

To explore how context influences SCE we asked three research questions: 1) How does SSI-based versus community-based framing survey modalities affect SCE? 2) does the type of chosen community matter to students' SCE? and 3) How does SSI-based SCE and community- based SCE change pre-to-post instruction?

Methods

The context of this study was a large, post-secondary science literacy course that used SSI of plastic pollution and flood mitigation. Students completed the PSCE survey as part of pre and post-course assignments. The instrument includes 14 statements which address the four subscales of SCE (Table 1). It was administered in two modalities: students in Spring (n=59) and Fall 2022 (n=70) completed the PSCE in the context of two communities, and students in Spring 2023 (n=79) were given the PSCE in the context of two SSIs (plastic pollution and flooding).

Students who completed the surveys in the community-focused modality answered PSCE items twice, first framed around civic engagement in the context of a resident in their state (prompted community). Then students were asked to identify a personally important community as the frame to complete the PSCE instrument. This choice was repopulated for the post-course survey (chosen community).

Pre-to-posttest differences were compared with paired t-tests for SCE within each of the survey modalities. These scores were also compared among the survey contexts and the categories of chosen communities using ANOVA, with pairwise comparisons made using Tukey's HSD.

Findings

In RQ1 we found that pretest SCE was significantly higher in both prompted and chosen community modalities compared to the plastic and floods SSI-topic modalities (Figure 1, $p < 0.001$ for all topic x community pairs). There were no differences in pretest SCE when comparing chosen community to prompted community ($p = 0.3$), while pretest SCE was somewhat higher for plastic than for flooding ($p = 0.02$).

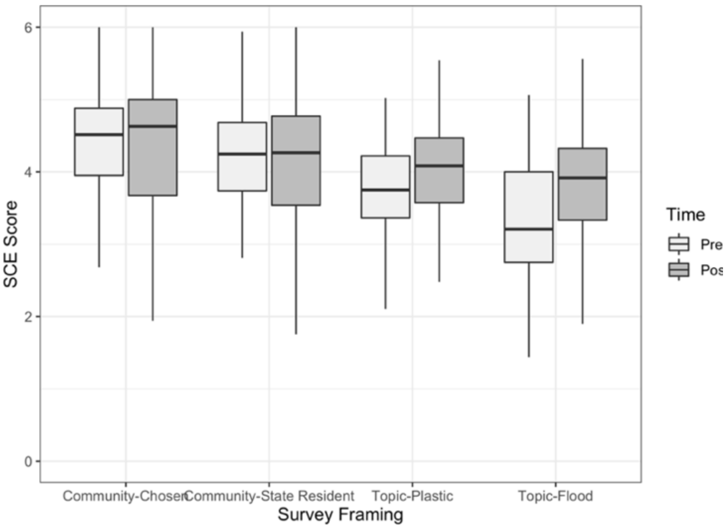

Figure 1: Pretest and posttest SCE in each context.

Category	Count
College	31
Demographic	27
Geographic	39
Interest	39

Figure 2: Category frequencies of chosen communities.

For RQ2, first we assigned students' chosen communities to a category (Figure 2).

There were significant difference among the categories of communities on the pretest ($p = 0.09$) and posttest ($p = 0.05$) and the change in SCE was marginally significant ($p = 0.11$; Figure 3), with college-community general lower SCE than interest-communities.

Different kinds of communities have been shown to foster different levels of civic engagement (Putnam, 1995), related to the way people engage with members of that community. Likewise, our previous work found that SCE increases with students' perceived cohesion with a community.

For RQ3, there were significant increases ($p < 0.05$) in SCE from pretest to posttest in both SSI-based modalities (plastic and floods), but no significant differences for either prompted or chosen community-based modality (Figure 1).

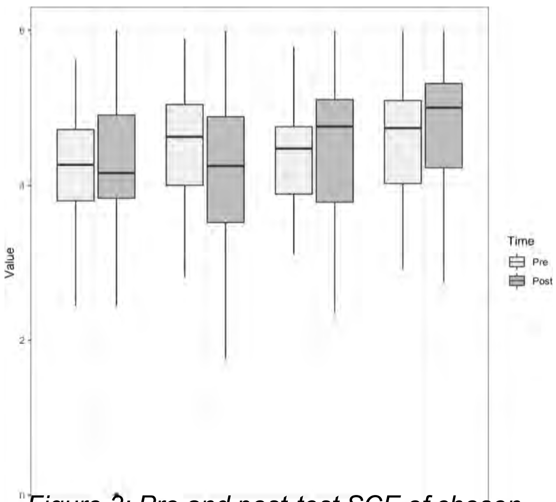

Figure 3: Pre and post-test SCE of chosen community categories

Conclusions

Context matters when evaluating scientific civic engagement in students. Students initially show higher civic engagement when asked to think about their communities rather than classroom-content SSI, but by the end of the course, their SCE increased for the SSI. When placed in the context of an SSI, increases in PSCE may be reflecting a change in content knowledge rather than a true increase in civic engagement potential. Regardless, more understanding is needed to enable transfer from SSI-based civic engagement in course contexts to civic engagement in a real-world community context.

SCE also varied based on the type of community that students chose, which may be related to community cohesion. Better understanding is needed about how students relate to their communities, and how to build SCE into that relationship.

The goal of SSI-based science literacy education is to enable students to apply learned skills to new problems. Current methods of instruction may not be reaching this goal, which motivates further research to better understand the relationship between skill-based competency and civic engagement.

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From poliomyelitis to covid-19, how to put biological knowledge at the heart of reasoning on vaccine ?

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Theoretical background or rationale
The Science-Technology-Society trend in education is an approach to scientific learning designed by Solomon (1983), Hodson (2003) then Kolstø (2005) which explicitly integrates the social context and the knowledge of students' daily lives to teach the interconnections and inseparability of science and society. Following this trend, we look at SocioScientific Issues (SSI) as potential opportunities to put authentic and valid knowledge into circulation.

Models for analyzing informal reasoning on SSI initially favored either cognitive practices (Sadler et al., 2007) or argumentative abilities (King & Kitchener, 1994) but no longer dissociate the analysis of arguments from that of the practice of reasoning (Bächtold et al., 2022).

Key objectives:
Implementing scientific investigations in the classroom about such complex and open-ended questions involves a dialogic approach which has been formalized by the SSIBL (SocioScientific Inquiry Based Learning) approach (Levinson & Amos, 2018).

Recognizing that the organisation of debates between students is sometimes tricky for teachers, we examine the potential of an alternative approach of SSIBL. To what extent does a documentary approach to SSI highlighting a paradox promote the circulation of contextualized and valid knowledge?

Research design and methodology:
We are particularly interested in the way in which students took into account elements of particular contexts to assess epidemic risks and uncertainties by mobilizing biological knowledge. They had to think about the vaccine strategy to fight two epidemics: "*By comparing the vaccination strategy concerning poliomyelitis with that concerning covid-19, and by taking up the elements of information seen during previous work, you will answer the following question: In your opinion, should vaccination against covid be compulsory or voluntary? For what reasons ?"*

We analyzed the productions of fifty-one fourth Year 9 students (13-14 years old) attending a secondary public school in an Educational Priority Area. Their productions are individual and do not come from a phase of exchanges between them: here it is a question of each person developing their opinion and taking a step back from it, without trying to convince the other students in the class, but by questioning the paradox[1] that the two situations raise. Yet, our analysis focuses in particular on the anticipation or not of a counter-argument in the justifications put forward by the students (in the Toulmin sense taken by Golder & Favart, (2003), meaning: a justification is a support for the argument).

Additionally, we scrutinize how they took into account the specific features of contexts and the uncertainties. Taking into account the contexts of epidemics (incidence, effectiveness of vaccines, populations at risk, etc.) is evaluated from 1 to 4: 1= the reasoning is general and the contextual specificities are ignored, 4= the reasoning is based on comparing the specificities of the two contexts. We also evaluated from 1 to 4 to what extent the students assign or not a domain of validity to their assertions: 1 = the student presents his assertions as general truths, without modalization, the domain of validity is not taken into account, 4= the student identifies and explains the scientific uncertainties in documents and speeches.

Findings:
23 students adopted, without questioning, a non-reflective mode of argumentation, in which the anticipation of counter-arguments has no place, since the assertions are presented as non- debatable truths. But among the 17 students who discussed the uncertainties and areas of validity of knowledge, it is remarkable that the vast majority (12) developed justifications which anticipated counter-arguments.

	The validity of the knowledge is examined			
	at level 1	at level 2	at level 3	at level 4
Potential counter-arguments are anticipated	**7**	**7**	**2**	**3**
No counter-argument is considered	**23**	**4**	**1**	**0**
Total	**30**	**17**		

For instance, within the response of student no. 36, we identify:

- a clear opinion: *I think that vaccination against covid must be compulsory*
- the expression of two justifications:

. *because it is the only way to stop covid or at least make it spread less*.

. *I also think that the vaccine is not dangerous*.

- the anticipation of a counter-argument: *If it was, the doctors would not have made it available to us.*

[1] The vaccine was compulsory against poliomyelitis diseases that was no longer present in our population in 2021, and the vaccine was not compulsory against the raging epidemic of covid-19 at the same time.

	The specific contexts of epidemics are considered			
	at level 1	at level 2	at level 3	at level 4
Potential counter-arguments are anticipated	**3**	**5**	**9**	**0**
No counter-argument is considered	**12**	**3**	**9**	**0**
Total	**15**	**8**	**18**	**0**

We observe that when the reasoning is general without taking into account the context of the considered epidemic, there is very little anticipation of a counter-argument (only three cases out of 12). But we also observe that with an increase in the level of contextualization of knowledge (level 2, then 3) there is also an increase in the number of students (5, then 9) who anticipate counter-arguments. Half (12 out of 24) of those who do not anticipate a counterargument do not consider the contexts, , while 14 out of 17 of those who anticipate counterarguments take into account elements of context in the two situations.

Let's have a look for instance at the response of student no. 20, in which we identify:

- a clear opinion: *The covid vaccine should not be compulsory*
- and a short justification: *because even if you get vaccinated you can catch it and spread it.*

This example clearly shows that student no. 20's reasoning goes beyond a general assertion on the effectiveness of vaccines, since the comparison of specific epidemiological contexts lead him to distinguish two aspects of the effectiveness of each of the vaccines considered: on the attenuation of symptoms, on the reduction of contagiousness.

Conclusions:

Our results show under what conditions a documentary approach to SSIs can be fecund: It appears that taking into account specific contexts (through the examination of particular vaccines in a given region and time) lead students to identify the biological knowledge at the heart of the debates. We note that this questioning of the specificity of contexts is all the more marked as students make the effort to anticipate possible counter-arguments in the justifications for their opinions.

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Bringing the real-world into the elementary classroom: A framework to identify opportunities to address Socioscientific Issues in the elementary school curricula in England, Italy, and Portugal

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Expanding horizons: Utilizing digital curation to foster students' engagement with SSI

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Theoretical background
Integrating socio-scientific issues (SSIs(into Biology education is essential to stimulate students' awareness of the ethical and personal ramifications of these issues. This approach aims to actively involve students in decision-making by harnessing their personal perspectives and experiences (Sadler, 2009). The online setting offers a wealth of information that can empower students to engage actively with SSIs (Klosterman et al., 2012). However, to be effective, students must first acquire the skills to navigate digital media platforms and identify reliable information, thus ensuring meaningful engagement with SSIs (Rawson Lesnefsky et al., 2023). Biology education has shifted towards actively engaging students in SSIs connected to daily experiences. However, there is a need for additional research to guarantee effective SSI engagement, especially in digital learning environments. Engagement encompasses various interconnected facets (Sinatra et al., 2015) and correlates with improved academic outcomes and an increased propensity to pursue future careers in science (Fredricks et al., 2004). The present study implemented Digital Curation (DC) as a pedagogical approach for digital teaching and learning SSIs, to explore its role in enhancing students' engagement with these complex issues.
DC consists of systematically selecting, organizing, and preserving digital items to create digital collections that provide valuable, relevant information on a particular subject (Author 3, 2020). DC as a teaching and learning practice is student-centered, enhances students' digital literacy, helps them navigate repositories of information, improves skills crucial in social media and online communities (Mihalidis & Fromm, 2014), and enhances critical thinking skills in the digital environment (Authors, 2023).

Key objectives:
This study aimed to characterize the dimensions of student engagement when addressing SSIs through DC (SSI-DC). SSI-DC can be conducive to fostering this engagement, given its alignment with authentic learning (Forkosh-Baruch & Gadot, 2021).

Research design and methodology:
This qualitative case study involving four teachers and 25 students examined whether and how SSI-DC promotes students' multidimensional engagement, and if so, which dimensions are manifested. Data were collected through semi-structured interviews with the teachers and students, and the teachers' reflective written reports. A content analysis was conducted to pinpoint instances of student engagement based on Sintra et al. (2015).

Findings:
The findings indicated that teaching and learning through SSI-DC enhances students' multi-dimensional agentic, social, behavioral, cognitive, and emotional engagement (Table 1).

Table 1. Engagement dimensions examples

Dimension	Teachers	Students
Agentic engagement	*"The students were asked to build a collection about any topic they chose to experiment with, and to design it by adding different types of content. I went around the class and saw how busy they were making their collections and uploading the items, both working as a group and independently."*	*"I chose this topic to learn more about it and form my personal opinion. It is important to me on a personal level".*
Social engagement	*"... In the DC I taught, I uploaded the materials and the students contributed what they found. The students could also look at others' collections worldwide… The DC allowed me to interact with the students as independent learners as well as working in a team. This consolidated the lesson and encouraged everyone to be involved in learning".*	*"The personal connection for me was the work in groups, learning with my classmates, and the cooperation throughout the activity."*
Behavioral engagement	*"They studied together even after school hours which suggests that they enjoyed the DC, they were active, and talking constantly. Even the students who did not participate in face-to-face lessons talked with their friends about the SSI, looked for information, and were more active in these classes."*	*"We started working in the classroom during biology class in the computer room. Afterwards the whole group worked together on Zoom in our free time."*
Cognitive engagement	*"When they are exposed to online content, more reliable sources that can strengthen their claim, it enriches their knowledge and the arguments they produce. The class discussion was also based on scientific evidence presented by the students. They shared correct pieces of information and backed up their statements after having read a scientific article or watched a video made by a scientist."*	*"I remember a video we watched but decided not to keep in the DC because there was no relevant information that responded to our topic so there was no need to use it ..."*
Emotional engagement	*"The students learned independently while searching for information and organizing it. DC is something you can use every day ... I was exposed to a new, enjoyable, and educational technique that is directly relevant to the students' lives."*	*"I got new information that resulted in significant changes in my lifestyle; DC is a different and novel way of learning".*

Conclusions:

The findings suggest that SSI-DC effectively involves students across all five cognitive, behavioral, emotional, social, and agentic dimensions of engagement. It empowers teachers to construct a more dynamic and immersive learning environment, which is advantageous when teaching SSIs, since it prompts students to engage in critical thinking and make better -informed decisions. By encouraging students to use digital media for communication, learning, and collaborative endeavors, DC cultivates a more active and interactive learning experience.

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Teaching with textbooks / newsletters and interdisciplinary teaching

Biology teachers' perceptions of the possible contribution of biology newsletters

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Theoretical background or rationale

Biology is a constantly evolving field, and for educators, keeping pace with the latest research, is crucial for providing high-quality instruction and fostering students' growth. Staying updated with new discoveries and insights regarding biological research, is of paramount importance since it has been shown to increase teachers' content knowledge (Gess-Newsome et al., 2019), termed lately Contemporary Content Knowledge of teachers (Traube & Blonder, 2023). Biology newsletters (BNs) offer teachers an accessible and concise medium to disseminate scientific research, breakthroughs, and relevant biological content to their students. BNs focus on theory and methods, similar to scientific articles, yet they also resemble popular articles that report the evaluation of authorized experts (Parkinson & Adendorff, 2004). The potential benefit of the BNs is to provide teachers with the means to engage students with scientific literacy as well as foster critical thinking skills (McClune & Jarman, 2012).

Moreover, BNs can serve as a catalyst for student engagement and curiosity. By presenting the latest scientific discoveries and breakthroughs in an accessible format, teachers can spark students' interest and inspire them to explore biology beyond the confines of the classroom and students can even learn to think like scientists (Hoskins, 2010). Yet, it is not sufficiently clarified what the advantages of the BNs are for teachers and students.

Key objectives:

The aim of this research was to investigate how teachers perceive the impact of BNs, named "Biology Weekly", on both their own professional development (PD) and the possible contribution to their students.

Research design and methodology:

During the 2022–2023 school year, 21 BNs dealing with biological topics were written and sent via WhatsApp to 901 biology teachers. The process of writing the BNs involved screening recent scientific journals for relevant articles to high-school biology curriculum, some dealing with NOS, and writing short, scientifically accurate BNs. The BNs were written in Hebrew and were translated to Arabic. All teachers received a questionnaire after the last BN was sent. Of these teachers, 110 answered the questionnaire, 86 female and 24 male, mostly high school biology teachers, coming from all over the country and with a wide range of teaching experience. The questionnaire included, in addition to demographic information, Likert type questions referring to the perceptions of teachers and their students (Table 1).

Table 1: The main part of the questionnaire sent to teachers.

A. Consider each of the following statements regarding your professional development as teachers:
How do the newsletters in "Biology Weekly" contribute to your professional development as a teacher?

	Strongly agree	Agree Partially	Agree	Disagree	Do not agree at all
1. As a source for acquiring current biological knowledge					
2. As a source for acquiring reliable biological knowledge					
3. As a source of biological knowledge that can be used for teaching					
4. As a source of knowledge related to the curriculum					
5. As a source of knowledge that extends beyond the curriculum					
6. As an opportunity to learn about how the scientist works					
7. As a way to learn scientific research skills (such as: information gathering, research planning, data analysis)					
8. As a way to raise questions to which you are not sure what the answers are					

B. Refer to each of the following statements regarding the contribution to your students:
How can the newsletters in "Biology Weekly" contribute to your students?

	Strongly agree	Agree Partially	Agree	Disagree	Do not agree at all
1. As a source for acquiring current biological knowledge					
2. As a source for acquiring reliable biological knowledge					
3. As a source of knowledge that extends beyond the curriculum					
4. As a source of information for a research work					
5. As an opportunity to learn about how the scientist works					
6. As a way to learn scientific research skills (such as: information gathering, research planning, data analysis)					
7. As a way to raise research questions and hypotheses					
8. As a way to raise questions to which you are not sure what the answers are					
9. As a way to increase students' interest in science					
10. As a way to increase the interest of students in the field of biological knowledge					
11. As a way to develop student's scientific literacy					
12.As a way to enable students to use scientific knowledge in diverse situations					

Using statistical analysis, we divided each section of the questionnaire to three subdivisions according to the main theme referred to in the statements included in this group (Table 2), basing our division on the framework of Gess-Newsome (2015).

Table 2: Division of the questionnaire to groups.

Group number	Statement number	Group name	Cronbach's α
1	A1,A2,A5	Biological Knowledge of Teachers (BKT)	0.90
2	A3, A4	Biological Knowledge for Teaching and Curricular Usage (BKTC)	0.76
3	A6,A7,A8	Scientific Literacy of Teachers (SLT)	0.85
4	B1, B2, B3	Biological Knowledge of Students (BKS)	0.88
5	B9, B10	Biological Interest of Students (BIS)	0.91
6	B4,B5,B6,B7,B8,B11,B12	Scientific Literacy of Students (SLS)	0.93

Findings:
We found that the two groups whose mean score is the highest are BKT (4.370 ± 0.076 (SE)) that deals with biological knowledge of teachers and BKS (4.348 ± 0.072 (SE)) that deals with biological knowledge of students. These two groups show that the main contribution of the BNs to teachers' PD and their contribution to their students is the biological knowledge.
The two groups whose score is the lowest are SLT (3.603 ± 0.092 (SE)) and SLS (3.586 ± 0.089 (SE)), both dealing with scientific literacy of teachers (SLT) and of students (SLS). There is a significant difference between the mean score of BKT and SLT (<.0001) and between BKS and SLS (<.0001). This finding shows that the BNs are much less important for the teachers as a way to raise their own or their students' scientific literacy than their importance to raise their biological knowledge.
Another interesting finding is that teachers see the BNs as important for promoting their students' biological interest (BIS). The mean score of this group is relatively high (4.286 ± 0.081 (SE)), with no significant difference between BKS and BIS. The meaning of this finding might be that the BNs are important for teachers in promoting their students' knowledge as well as their interest in biology.

Conclusions:
The key findings revealed that the primary contribution of the scientific newsletters lies in enhancing teachers' Contemporary Content Knowledge (following Traube & Blonder, 2023) and students' biological knowledge, and by that contributing to the teachers' PD. Additionally, the findings indicated that the BNs contribute less to teachers in terms of elevating their own or their students' scientific literacy. This finding aligns with the notion that 'scientific literacy' is an aim for school science education, yet there is less agreement on how it should be put into operation (McClune & Jarman, 2012). This research may lead to an in-depth qualitative analysis regarding the contribution of the BNs to teaching methods and to student success.

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Students' terminological and conceptual understanding of interdisciplinary teaching

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Theoretical background or rationale

Interdisciplinary education is the answer to the demands of a modern, increasingly interconnected and changing world. In order to deal with current challenges, interdisciplinary competencies such as connected thinking, critical thinking and problem-solving skills are increasingly important and can be specifically promoted through interdisciplinary projects in schools (Authors anonymized, 2022; Brassler & Dettmers, 2017; Stentoft, 2017; Ye & Xu, 2023). In addition to fostering interdisciplinary competencies, the concept is considered to have other advantages, such as promoting interest or contextualization, making interdisciplinary teaching increasingly important (Authors anonymized, 2021; European Council, 2018; Ye & Xu, 2023). At the same time, teachers improve their professional skills and knowledge while gaining awareness of boundaries and connections between subjects. (Tonnetti & Lentillon- Kaestner, 2023). Secondary schools rarely implement the concept, and if they do, it tends to be multidisciplinary rather than interdisciplinary, which limits its impact (Tonnetti & Lentillon- Kaestner, 2023). One reason for this issue may be the subject-specific preparation of pre-service teachers, which leads teachers to see themselves primarily as subject experts rather than teachers (Tonnetti & Lentillon-Kaestner, 2023). There is barely any preparation for interdisciplinary teaching. As a result, teachers communicate barriers to practical implementation in the form of lack of acceptance toward the concept, organizational concerns, narrow curricular specifications, and unwillingness to cooperate within the college (Hasni et al., 2015; Margot & Kettler, 2019). However, the success of implementing interdisciplinary instruction seems to be highly dependent on teachers' perceptions and experiences (Tonnetti & Lentillon-Kaestner, 2023). Therefore, it is important to assess students' and teachers' terminological and conceptual understanding and their perceptions to improve teacher education and promote interdisciplinary teaching in schools.

Key objectives:

Given the importance of teacher education in promoting interdisciplinary education in schools, it is crucial to assess students' pre-existing knowledge to effectively address potential barriers. This is particularly important given the varied understandings of interdisciplinary education. Therefore, the question is posed: What terminological and conceptual understanding do students have regarding interdisciplinary teaching?

Research design and methodology:

For this purpose, a qualitative study design was chosen. A questionnaire with closed and open questions was developed. The questionnaire was distributed to N=165 students pursuing bachelor's (n=83) and master's (n=82) degrees in teaching at a German university in the period from 2020 to 2021. All students studied biology and an additional second subject. Students were tasked to define interdisciplinary teaching and provide a concrete teaching example based on their terminological understanding. The results underwent qualitative content analysis according to Mayring (2015). Both deductive and inductive methods were used to create the categories. German and English definitions were analyzed as a theoretical basis and categories were derived. After reviewing the material, we defined five main categories: ‘combined subjects’, ‘content’, ‘method’, ‘objective’, and ‘time’. Currently, a second person is coding the data to ensure analysis quality through inter-rater reliability.

Findings:

An initial analysis showed, that the interdisciplinary teaching definitions often focus on the number of subjects, content, and methodology. The most central characteristic of interdisciplinary teaching formats is the inclusion of different subject perspectives. In most definitions, teaching is still located in the individual subjects. Either references are made to other subjects or a central topic connects the subjects. The prior understanding is thus more likely to be multidisciplinary than interdisciplinary, which is considered to be comparatively less effective. Moreover, the students do not specify what kind of topics are suitable for interdisciplinary elaboration. Upon initial observation, it appears that the students may not fully comprehend the practical applications of the concept. In addition, only very few definitions dealt with the objective of interdisciplinary teaching. It becomes apparent that the students have a basic idea of the methodological and content dimensions but do not understand what objective is to be achieved. The objective and benefit of interdisciplinary teaching for both instructors and learners remain ambiguous for them.
In the presentation, we will analyze the outcomes in more detail and deliberate on the degree to which learners possess the self-assurance to instruct in an interdisciplinary manner, grounded in their own understanding.

Conclusions and outlook:

It becomes evident that particularly the intention of interdisciplinary teaching is not tangible and that there is only a limited pre-understanding of suitable topics or contents. For the effective preparation of student teachers for the increased implementation of interdisciplinary teaching, it is important to take into consideration the previous understanding and transfer it into suitable teaching formats. Therefore, a good-practice model for the training and further education of (prospective) teachers is presented in an outlook.

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How do Grade 10 to 12 teachers use textbooks in Biology classrooms?

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Introduction and Background
In this study, we report on South African teachers' self-reported use of textbooks for instructional decision-making and teaching. Among the many factors that can influence students' learning and academic achievement are textbooks (Reddy et al., 2022). It is often stated that most teachers use textbooks in their classrooms, but what is seldom discussed is *how* they make use of the textbooks. The main objective of this study was to develop an understanding of how teachers use textbooks in their Biology classrooms. Textbooks are didactic tools that are extensively used by teachers and they play a central role in interpreting and implementing the curriculum (Hadar, 2017). They provide structured content, organise teaching and learning and enable the development of thinking and understanding of the subject (Hadar, 2017).

This study was conducted in South Africa, a lower performing country as measured in the latest TIMSS study, where only thirty-six percent of learners could effectively apply and communicate their understanding and knowledge of science (Reddy et al., 2022).

Framework
We contend that the ability of teachers to conduct in-depth interrogation of the textbooks depends on their Subject Matter Knowledge (SMK) and their Pedagogical Content Knowledge (PCK) (Ball et al, 2008). The framework that underpinned this research focused on textbook utilisation during the enacted PCK in the classroom (Carlson and Daehler, 2019).

Method
This qualitative case study, in the interpretive paradigm, involved in-depth semi-structured interviews with 13 secondary school teachers, from both government and independent schools , teaching Grades 10 to 12 in Gauteng Province of South Africa. Data were collected to saturation, transcribed and coded, before themes were identified. The self-developed instrument posed three main questions: How do teachers use textbooks during instructional planning? How do teachers use textbooks in the classroom during instruction? and How do teachers use textbooks in the context of assessment?

Findings and Discussion
Teachers did not choose textbooks based on quality criteria, nor used a deliberate selection process. Apart from three, teachers did not indicate a preference for specific textbooks, and they indicated that textbooks were chosen mostly by senior staff. Only one teacher said the decision was made collaboratively. Teachers simply accepted the textbooks that they were using and most gave the impression that they made do with what they had. In most cases, except for the independent schools, books were provided to learners, but they had to return them for the next cohort to use. This locked teachers into using one textbook for several consecutive years. Schools also did not use textbooks from the same series for different grades, but often, every grade had a textbook from a different publisher.

Teachers did use their textbooks for preparation, but this was mostly limited to finding suitable diagrams, images or assessment questions and activities for preparing PowerPoint slides that they taught from. PowerPoints were shared with learners. The teachers were profoundly examination-driven and did not welcome texts that could enhance conceptual understanding beyond the confines of the examinable curriculum. The guidelines that the teachers followed very closely for sequencing and deliniation of their content, were the curriculum document in combination with the preferred Annual Teaching Plan (ATP) (government schools), or the Independent Examination Board curriculum (IEB) (independent schools).

Most of the participants wanted textbooks to follow these documents closely and not deviate from examinable content in the slightest; any deviation had to be clearly indicated. For this purpose, they often found the ATP to be a sufficient guide, rather than their textbooks or curriculum. Teachers eshewed the opportunity for textbooks to increase their repertoire of subject matter knowledge and pedagogical content knowledge, as they felt that such additions in textbooks could confuse learners. They did not question the suitability of the guidelines for conceptual understanding of Biology content. In contrast with the view of Davis and Krajcik (2005) that textbooks should enhance teacher knowledge beyond the grade they teach, teachers gave no sense that students and teachers could be required or encouraged to know Biology content outside of examinable content.

No participant reported using the teachers' guides that are available for most of the textbooks.

Students with access to their own textbooks show higher achievement than learners who share or who do not have textbooks (Reddy et al., 2022). In this study, all students had access to textbooks, whether hard or electronic copies, but few teachers regularly used these textbooks in class. Some teachers even suggested that they had been instructed not to use textbooks in class, and students discouraged to bring them to school.

Teachers used some of the classroom activities from textbooks, but seldom for formal assessment purposes.

Some clear differences were seen between novice teachers (one to four years experience) and experienced teachers. Novices used textbooks with fidelity; experienced teachers became more flexible in textbook use.

Conclusion
Teachers did not exploit the affordances of textbooks to their full potential. Teachers mainly used textbooks to prepare students for their examinations. In future, teacher training in the utilisation of textbooks should be investigated. Further research is needed in schools in economically disadvantaged areas, and students' interactions with their textbooks should be examined.

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Evolution content of School Textbooks: evidence from eight European countries

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Theoretical Background

Understanding evolution is fundamental to understand the world and to address a several socioscientific problems such as biodiversity loss, climate change, health or food security etc. (Sá-Pinto et al., 2022). However, the theory of evolution is not understood by many people in Europe (Kuschmierz et al., 2021). Textbooks play a significant role in education purportedly accounting for 75%–90% of instruction and 90% of all teacher-assigned homework (Chiappetta et al., 2006). To date, the few studies analysing the evolutionary content of biology textbooks focus on the historical presence of evolution in textbooks (Miller, 2010), the presence or absence of particular topics (Asghar et al., 2014); evolution misconceptions (Prinou et al., 2011) and evolution integration across the curriculum (Nehm et al., 2009).

Key objective

This study's objective is to analyze the presence of evolutionary concepts in biology textbooks across eight European countries.

Research Design
We analysed the science and/or biology school textbooks in use during the school year 2020-2021 in Belgium, Cyprus, Czech Republic, Greece, Italy, Netherlands, Portugal and Slovenia. We analysed the most commonly used textbooks from the 1st until the 9th grade as this is school period surveyed by PISA and the 9th grade is the end of the shared compulsory curricula in most of the analysed countries.
A content analysis was performed, using paragraphs, images, text with images or activities as units of analysis (Chiappetta & Fillman, 2007) and the Framework for the Assessment of school Curricula on the presence of Evolutionary concepts (FACE; Sá-Pinto et al., 2021). FACE includes six categories (History of Life, Evidence for Evolution, Mechanisms of Evolution, Studying Evolution; Nature of Science and Scientific Practices) and 35 subcategories.
At least two coders independently analysed each textbook and attributed a code to each unit, corresponding to the categories and subcategories.
Consensus was reached through discussion of conflicts and disagreements between coders for the units and their coding (Lombard et al., 2004). Chi- square test were used to test for the differences in the distribution of the FACE categories and subcategories among the countries' textbooks.

Findings
Differences were found between countries in the number of references to evolution learning goals (Figure 1) and on the frequency of the six FACE categories ($p<.001$, Figure 2). For most countries, 30% or more of the learning goals important for evolution understanding are not addressed (Figure 3).

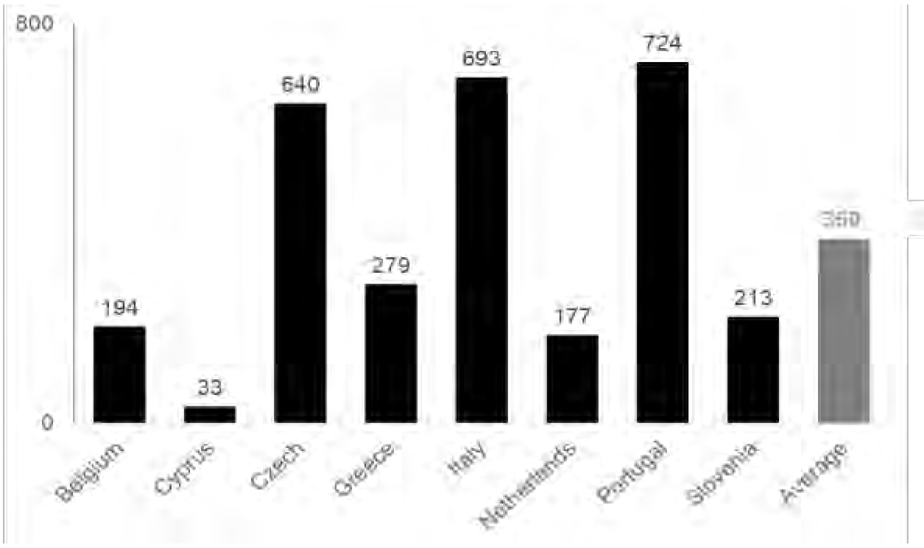

Figure 1- Total references to evolution in school textbooks (grades 1-9) per country.

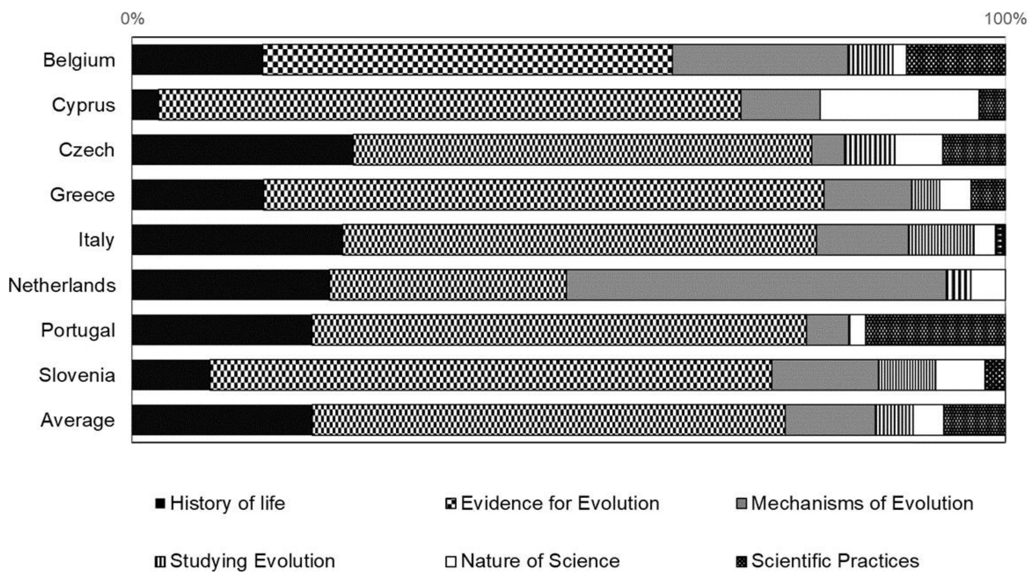

Figure 2- Relative frequency of each FACE category in the textbooks of each country when all grades are considered.

Analysing the subcategories we observe that:

1. The most frequently addressed learning goals are promoting basic abilities to recognise the existence of biodiversity or address the relationship between form and function what may promote evolution misconceptions if not explored at the light of mechanisms of evolution.
2. Concepts addressing the mechanisms of evolution are often not included (as for genetic drift and sexual selection) or not emphasized (as for natural selection) nor used as unifying concepts;
3. Half of the countries do not address the implications of evolution in our daily life.

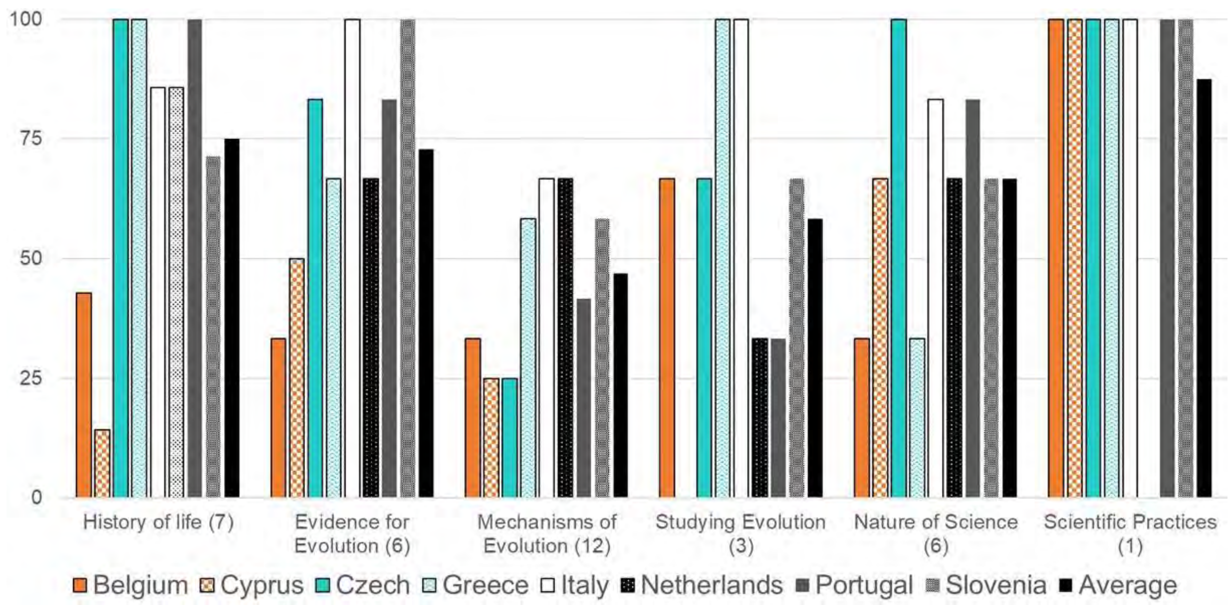

Figure 3- Relative frequency of each FACE category in the textbooks of each country when all grades are considered.

This is not a comparative study between the countries included in this study as in some of these there are many textbooks available for each grade. We should also highlight that teachers can complement textbooks with additional resources and activities.

Conclusions

Our results highlight that the textbooks most widely used from the 1st to the 9th grade in eight European countries exhibit important deficits in the way they cover evolution. It is important that:

1- textbook more deeply explore evolution and evolutionary processes starting from the first school years avoiding reinforcing students' misconceptions.

2- evolution is integrated in other biology topics as a unifying concept throughout students' learning progressions (Nehm et al., 2009) and highlighting its relationship with socioscientific issues (Sá-Pinto et al., 2022).

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SYMPOSIUM

Teaching Biodiversity

Species knowledge portfolios – Fostering species knowledge and coherence perception of pre-service biology teachers

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Theoretical background

The decline of biodiversity on all its levels poses a global threat. Major drivers for the crisis are human interventions in nearly all terrestrial and marine ecosystems (Bongaarts, 2019). Another future problem is the reduction in number of so called „species knowers“, meaning knowledgeable citizens and experts for certain taxa (Frobel & Schlumprecht, 2016; Wheeler, 2014). Furthermore the representation of taxonomical content in western research literature is declining (Langer et al., 2021). Not least a decrease of species knowledge can be observed in wide parts of the population. Many empirical studies show this trend in particular for students and pre-service teachers over the last decades (Gerl et al., 2021; Gerl et al. 2018; Sturm et al. 2020; Hesse, 1983). Also surveys at the university of Rostock show that the initial level of species knowledge at the beginning of the biology studies is very low as well as among secondary school students. Indications for the correlation between species knowledge and action competence regarding preservation of species and habitats give for instance Sturm and Berthold (2015) or Blessing (2007), which assume species knowledge as a foundation for sustainable development of society, preservation of biotopes and commitment for preservation actions. In this context it has to be pointed out that the term species knowledge (ger.: Artenkenntnis) isn't defined or used homogenous at all. Gerl and Aufleger (2022) classify the knowledge or recognition of species into „Formenkenntnis“ (assignment to a higher taxonomic group), "Artenkenntnis“ (defining and naming of species) and contextual or deeper knowledge of species (e. g. behavior). Another concept regarding the knowledge of species poses species literacy. It involves knowledge of biodiversity and deep knowledge of specific species as well as skills for species identification (Hooykas et al., 2019).

Key objectives

Even though there are several courses addressing species knowledge in biology studies in Rostock the effects are not persistent. In addition to the mentioned low levels of species knowledge at the beginning of biology studies we can identify a lack of coherence between courses and topics. Coherence is here defined as the "informal-individual coherence" meaning the cognitive perception of the significance and the relations of contents (in this case regarding species knowledge) etc. (Cramer, 2020). A high degree of perceived coherence has positive effects on attitudes and knowledge processing (Hellmann, 2019). Informal-individual coherence can as well be established by active reflection and relation of contents. Another method for this purpose is working with portfolios. The other way round so called "course portfolios" provide the potential for the reflection of knowledge and the establishing of connections between course contents (Winter, 2013). Thus we ask following research question:

To what extent is a course accompanying portfolio suitable for fostering pre-service biology teachers species knowledge and coherence perception?

Research design

In three sub-studies we evaluate and improve the intervention according to the design-based-research approach. The testing begins in winter semester 2023/2024 (sample group: approximately 60 pre-service biology teachers and 60 bachelor students). In sub-study I we gather data of the botanical and zoological species knowledge (regarding all three levels proposed by Gerl and Aufleger) with two pretests and one posttest at the end of the second semester. In this time there are several lectures, excursions and identification courses addressing species knowledge.

For the mentioned surveys of beginning pre-service biology teachers we tested the “Artenkenntnis” for ten local seed-bearing plants via visual classification method (Buck et al., 2019). For the botanical (pretest I) and zoological (pretest II) we use an adapted questionnaire from the cited study of Buck and colleagues to query “Formenkenntnis”, “Artenkenntnis” and deeper knowledge.
Sub-study II aims to measure the effects of an intervention via course portfolios accompanying a biology didactical seminary on species knowledge in the third semester. The portfolios address species knowledge in teaching context. Sub-study III measures the coherence perception at specific time stamps during the whole study. Coherence perception draws through the research design as superordinated concept by displaying species knowledge as „big idea” of biology. The relevant horizontal and vertical dimensions of coherence are shown in figure below (fig. 1).

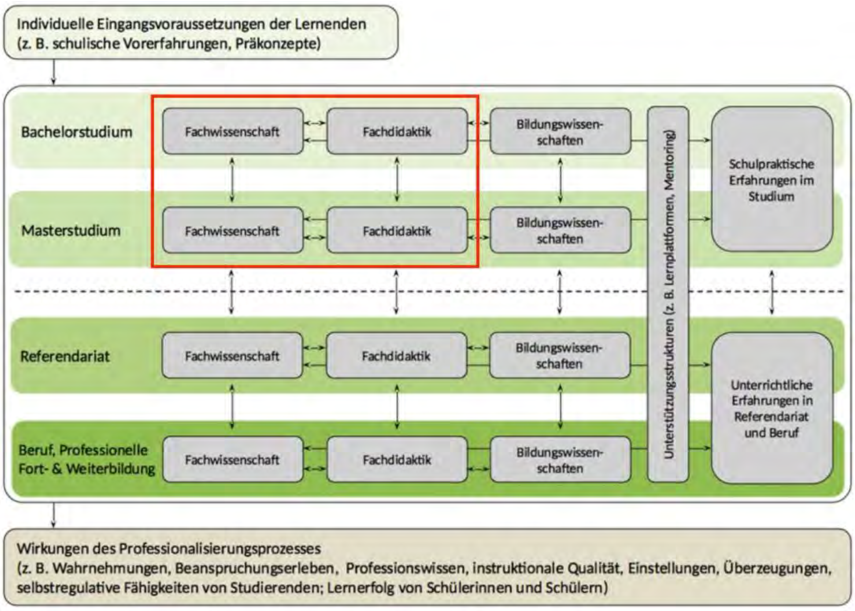

Fig. 1: Freiburger-pillars-phases model (Hellmann, 2019 S. 18)

Results
As key results for the years 2021 und 2022 we got the following:

	2021	2022
mean correctly named species	0,94	1,16
SD correctly named species	1,22	0,90
mean correctly named family	0,43	0,23
SD correctly named family	0,98	0,56

The exact distributions for the species names are shown in the diagrams below (fig. 2).

Fig. 2 Distributions of correctly named species

Pretest I and II are being currently carried out. The results are to be presented at the conference.

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Save the yellowed-bellied toad - the impact of a conservation program on students' motivation and relationship with nature

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Actions for Insects – An action-oriented intervention on biodiversity and insect conservation

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Rationale

Insects play a vital role in maintaining ecosystem balance and provide essential ecosystem services that directly benefit humans. They have various roles in nature, such as predators, prey, pollinators, and decomposers, influencing how ecosystems function. Unfortunately, many groups of insects are rapidly declining, and researchers warn from the potential consequences of this decline for both humans and natural food webs (Cardoso et al., 2020).
Scientists argue that we must take actions to support insect biodiversity now and educate the public to take action (Harvey et al., 2020). Thus, it is essential from a sustainability perspective to teach about the issue of insect decline in schools and equip students with the relevant skills to support insect biodiversity. Teaching about these topics also fits to key concepts in biology and science education (e.g., sustainability, ecosystem services, biodiversity). However, educational research about students' personal perspectives in the context of insect decline and insect conservation is very limited (Ruck & Mannion, 2021).

Key objectives

A first objective of the presented project is to design a teaching intervention that helps students to develop competencies to take actions for insect conservation.
A second objective is to investigate how the self-perceived action competence for insect conservation changes through this intervention.

Research design and methodology

The intervention design builds on the theoretically underpinned concept of action competence, which describes peoples' ability to address complex problems (Sass et al., 2020). The design aims to support learners' action competence by building on specific criteria (action-orientation, holism, pluralism) that are beneficial for fostering learners' action competence (Sinakou et al., 2019). The teaching design was adjusted to the age group and the biology curriculum of Swedish compulsory schools in grades 7 and 8 (12-15 years). The resulting intervention was then implemented at four schools in a Swedish municipality in spring 2022.
The development of students' self-perceived action competence through the intervention was investigated quantitatively in a pre-post setting. The investigation focused on the three dimensions of self-perceived knowledge, confidence and willingness to take actions for insect conservation. The sampling consisted of an intervention group (pre-test: n=190, post-test: n=137) and a control group (pre-test: n=99, post-test: n=86) receiving regular biology lessons. The quantitative data was analysed using descriptive statistics and t-tests in IBM SPSS.

Outcome & Findings

A first outcome of the project is the theoretically grounded teaching intervention "Actions for Insects", which is the first intervention building on the concept of action competence for insect conservation. The intervention consists of three phases. In the first phase, students learn relevant background information about insects and insect decline. Additionally, students work with iNaturalist as a digital tool for exploring insect biodiversity and the students search for insects at the schoolyard. At the end of the first phase, students plan their own actions to support insects. These actions can be anything that directly supports insects (e.g., growing insect-friendly flowers) or indirectly (e.g., informing others about actions). In the second phase, students have time to take these planned actions. Students decide for themselves which actions to take and how to proceed. During this phase, students are encouraged to take pictures of insects and upload them to iNaturalist. In the final third phase, students have the opportunity to reflect on their actions and on their role as researchers in iNaturalist.
A second outcome are the results from the pre-post-study that accompanied the implementation of the teaching intervention. On average, students had significantly higher values in the post-test after the intervention for the self-perceived knowledge, confidence, and willingness to take insect conservation actions. The largest effect sizes were observable for the self-perceived knowledge and the confidence. The students' in the post-test after regular biology lessons in the control group had significantly higher

values only for the self-perceived knowledge, whereas the self-perceived confidence and willingness did not change significantly. The effect sizes of all changes in the control group were smaller than in the intervention group.

Conclusions

The developed teaching intervention “Actions for Insects” proved to be effective in supporting the development of students self-perceived action competence, by fostering all three dimensions of knowledge, confidence, and willingness. We can conclude that students particularly need specific action-oriented knowledge (Which actions are effective? How to take these actions?). A novel aspect of the intervention is that it encompasses a variety of insects, going beyond teaching methods that focus on individual species. By this, the research project provides new insights for biodiversity education that are from high international relevance. The teaching design is open in the sense that it can be easily adjusted to other countries, school specific needs, and students' prior knowledge. At the symposium, we will discuss how the intervention and underlying concepts of action competence and action-orientation can contribute to effective biodiversity education in general, based on the findings from this study.

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Citizen science by monitoring wild bees and wasps with digital specification and nesting aids

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Aquatic plants – omitted topic in biology education

Aquatic plants – omitted topic in biology education

Theoretical background or rationale

Aquatic plants are an inseparable part of aquatic ecosystems contributing significantly to the biodiversity of these ecosystems (Pokorny & Kvet, 2004). They fulfil a wide range of ecological roles and contribute substantially to the structure, function and service provision of aquatic and wetlands ecosystems (O'Hare et al., 2018). Due to the consequences of global climate changes like torrential rains, flooding, increasing temperatures and eutrophication the biodiversity of aquatic plants decreases significantly which can lead to the degradation of wetlands. For the conservation of the biodiversity of aquatic species broad public knowledge and proper understanding of their ecological role is necessary, which could be reached via school education. Unfortunately, biology teachers cope to the phenomenon of "plant blindness" (Wandersee & Schussler, 1999), describing human ignorance of plants in their environment. The international literature does not provide any information on the level of pupils' knowledge of aquatic plants or the state of teaching of this topic in schools. This is the first monitoring study done in South Bohemia, Czech Republic, area with lot of wetlands and artificial fishponds, where aquatic plants create important part of human environment.

Key objectives:

Didactic survey was done at Czech lower secondary schools in order to: a) investigate the level of students' knowledge of aquatic plants and their ecophysiological role, b) monitor the state of teaching and teachers' opinion on the implementation of aquatic plants into biology education. Do biology teachers in this area include aquatic plants into their teaching practice? If yes, by which ways? If not, what are the reasons?

Research design and methodology:

To answer these research questions, didactic survey was done among 272 lower secondary school students and 30 their biology teachers at 10 school in the South Bohemia, Czech Republic. This area is known for having lot of artificial fish ponds, among others also Ramsar site and the UNESCO Biosphere reserve Trebonske rybniky, known European complex of wetlands and multitude fishponds. Hence the students as well as the teachers are faced frequently to aquatic and wetlands plants and physiological processes of these plants influence significantly their environment. The research instrument in both respondents' groups was the questionnaire. In case of students this questionnaire consisted of two parts. The first one was aimed on the knowledge of aquatic plants: the students were asked to name spontaneously aquatic plants and explain which species of plants create algal bloom. The second part consisted of 6 questions (multiple choice and open type questions) and was aimed on the knowledge of the ecological role of aquatic and wetlands plant for water and wetland ecosystems. The teachers were asked, if they include aquatic plants into their botany courses and by which way, if they consider aquatic plants and their ecological role as important to be tought (assessment on the 5 grade Likert scale) and why. The results were analyzed using the descriptive statistics methods (The STATISTICA 12 PC package, Stat Soft Inc.)

Findings:

The results of the survey done among the respondents living in the area with lot of wetlands and ponds show, that despite aquatic plants create significant part of their environment, the students' spontaneous knowledge of aquatic plants species is limited. The students named just 3 species: water lily (24 % of responses), yellow water lily (3 %) and reed (3 %). The majority of the respondents mentioned just taxonomic groups: algae (64 % of respondents) and blue- green algae (23 % of respondents). Just 14 % of respondents knows, that algal bloom is created by blue-green algae, but only 2 % explained properly that the algal bloom is a consequence of high nutrient load from the catchment. The students considered aquatic plants as producers of nutrient for other aquatic organisms, surprisingly they do not consider them like oxygen producers. Also, the teachers mentioned aquatic plants just rarely during their biology courses and mostly as primary producers for aquatic ecosystem only. Just 2 teachers use aquatic plants for practical experiments, one of them uses in situ field experiments in local fishpond. The students participating at this these experiments showed significantly better knowledge of ecological functions of aquatic plants and also better spontaneous knowledge of species compared to other respondents.

Conclusions:

Although aquatic plants play important role in our environment, the level of student knowledge, even among respondents living in areas where they commonly encounter these plants in their daily lives, is low. The low spontaneous knowledge of plants found in their immediate environment can indicate the signs of the plant blindness phenomenon. Even teachers do not include aquatic plants in their teaching often, most of them do not feel themselves sufficiently informed about the function of aquatic plants during their professional training. Another reason for not including this topic in their teaching cited by the teachers is lack of time during their biology courses. Significantly higher knowledge of aquatic plants and their ecological functions among students whose teachers included practical experiments in their lessons suggests a positive effect of practical teaching (especially in an ecological context during field experiments) on aquatic plant knowledge. The results of this initial study are limited by the small number of respondents and need to be confirmed by further research.

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Sex Education / Gender Identity

Sexuality, relationships, and identity in Swedish teacher education

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Theoretical background/rationale

Swedish comprehensive Sexuality education has been criticized for not meeting demands that exist from individuals and society, for example in the form of conflicting cultural sexuality norms and increased access to pornography. As a reaction to the shortcomings, changes have been made, and in Swedish schools the knowledge area is now called sexuality, consent, and relationships. For the changes to be feasible, a new degree goal has been added to the teacher training courses for elementary and subject teachers stating that the student must demonstrate the ability to communicate and reflect on issues related to identity, sexuality, and relationships (The Swedish National Agency for Education, 2022). Speaking in favour of this change are studies pointing to a relationship between teachers' willingness to teach about sexuality and relationships and their perceived knowledge and training in the area, and that they see sexuality and relationships as an important area of knowledge (Cohen, Byers & Sears, 2012; Costello et al., 2022). For the teacher training to contribute that knowledge to students, the degree goal needs to be transferred into learning activities and course goals in syllabuses of today's teacher training courses.

This project sets out to examine how teacher training transforms governmental requirements into curricula. This will be made through discourse analysis (Fairclough, 2003), implying an analysis of particular ways of talking and understanding cultural aspects of the world, in this case course syllabuses.

Key Objectives

The purpose of the study is to identify how the requirements expressed in the teacher training degree goals are transformed into course syllabuses. This is the first step in a project where changes in teacher education's teaching of sexuality, identity and relationships are investigated.

Research design and methodology

In the study, course syllabuses from twelve Swedish teacher education programs for both primary and secondary student teachers were analysed. In total, 34 syllabuses from six universities/teacher education programs were analysed with critical discourse analysis (CDA) (Fairclough, 2003) and capability (Nussbaum, 2000). Within CDA, *intertextuality* (I), *modality* (M) and *transitivity* (T) were chosen since they focus on how texts are transformed through different levels. Intertextuality means that all texts to some extent contain parts of other texts although developed, reinterpreted, simplified, and changed in different ways. Modality refers to the interpersonal function of language. An utterance can be more or less categorical and modality is associated to modal auxiliary verbs such as must, may, can and should. Transitivity deals with types of process which are coded in clauses and participant involved in them (Fairclough, 2003), implying focus on social agents and their actions.

Capability describes an individual's real freedoms to achieve their potential *beings* and *doings*, which are shaped but not defined by the circumstances, opportunities, and individual faculties an individual is faced with (Nussbaum, 2000). In this context, capability is regarded as something a student teacher should be supported to be and do, but also in some meanings are expected to be and do. In this way, there is a correspondence between transitivity, modality and capability.

Findings

The findings show a high degree of intertextuality with respect to degree goal and course syllabuses. In fact, some institutions did not develop the degree goal into any kind of advanced course related item. In those cases, we can identify there has been a process to transfer the degree goal into the course setting the advancement mainly refers to the characteristics of students' learning. That is, the degree goal "*The student should - demonstrate the ability to communicate and reflect on issues related to identity, sexuality and cohabitation*" was for example transferred into

- The student should be able to reflect on and create conditions for students' health and well-being in issues related to identity, sexuality and relationships.
- The student will be able to identify and critically examine norms and values related to sexuality and relationships.
-

The findings suggest that many course syllabuses almost are copies of the governmental degree goal. Many of the syllabuses contains similar wordings. In other words, the intertextuality is high within course syllabuses from different universities. Furthermore, the syllabuses are totally dominated by the word will. This wording demonstrates a modality that emphasises student teachers' capability.
The syllabuses are distinct about what student teachers should be able to do after the course.

Conclusions
The high degree of intertextuality can be interpreted in different ways. It can be interpreted as that the universities emphasise the wording from the governments in order not to leave anything behind. However, it can also be interpreted as the universities have not processed the syllabuses, but stick to the degree goal wordings of a general level that is the same for both elementary and subject teachers. It is then up to the teachers of each course to interpret the formulations and transform them into teaching. That interpretation raises the question of transparency regarding how the new degree goal is implemented in courses and whether the expectations of a changed sexuality education will occur.
It has not been possible to analyse transitivity and its processes and agents, involved in the interpretation and formulation of the course syllabuses, within this document study. This will be made in a future interview study. During our presentation, we are interested in discussing teacher training with respect to comprehensive sexuality education as well as the processes regarding transformation of degree goals to course syllabuses.

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Socio-scientific questions to transform conceptions on the teaching of sexuality in training biology teachers

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Theoretical background or rationale
Sexuality is an integral component of human health, which includes social and cultural aspects, and its education is articulated with Education for Health (EpS), within the framework of its Affective-Sexual Dimension (Aliaga et al., 2016). Sexuality is built from the affective dimension of the human being and constitutes a multidimensional process that characterizes each being in the social and personal (Grotz et al., 2020). Likewise, it is currently known that sexual behaviour, in addition to being related to the biological aspect (sex), is a social construction in which psychological factors such as feelings (neural networks that determine mental expressions), emotions (responses to internal and external stimuli) and affections (valences given to said feeling) (Damasio, 2018). On the other hand, the training of science teachers has been a process that has been culturally linked in different latitudes to sexual education. In this praxis, it has been shown that the beliefs, attitudes, conceptions, and training of teachers are closely related to the practices and discourses that they establish in the classroom around sexuality (Plaza, 2015), significantly influencing the construction that future citizens make about personal and collective sexuality (Plaza & Meinardi, 2021).
These assumptions have motivated the design, execution, and testing of a didactic strategy based on the Socio-Scientific Issues (CSC) model (Martínez & Villamizar, 2014) that allow critical analysis of sociocultural phenomena associated with sexuality from a biopsychosocial and affective perspective, such as gender violence, interpersonal relationships, contraceptive use, adolescent pregnancy, and sexual diversity.

Key objectives:
This study has characterized the contributions of a didactic intervention based on CSC in the conceptions about the teaching of sexuality of biology teachers in training, from southern Colombia.

Research design and methodology:
This research is mixed, non-experimental and descriptive and interpretive in scope. In it, during the year 2020, a didactic intervention with four units is designed and applied, using CSC: the body and the principle of otherness; affective relationship and communication; pleasure and eroticism; and ethics and responsibility. In addition, a questionnaire with 20 questions on sexual health from an affective-sexual perspective is applied before and after the intervention to 50 teachers in training of the "Bachelor of Natural Sciences-Biology". The teachers' conceptions about the teaching of sexuality were classified into six categories: 0- Does not know does not answer 1- Inclusion only of biological knowledge 2- Approach to prevention and promotion of sexual health 3- Historical and epistemological studies of sexuality 4- Sexuality as a socio- scientific phenomenon 5- Sexuality as part of health education. The content analysis technique was used to establish discourse networks and interpret the teachers' conceptions. In addition, student t-tests were carried out for paired samples.

Findings:
Teachers' conceptions of the nature of sexuality
The results regarding this category show that most teachers in training, before their participation in the didactic intervention, presented reductionist tendencies about sexuality framed in a model of sexual education of a clinical-preventive nature and in a perspective of control and risk prevention (Aliaga et al., 2016) (Figure 1). However, after the didactic intervention based on CSC, the teachers in training were mostly located in tendencies that recognize models of a biographical-professional nature, on sexual education, that value the importance of sexuality in the cultural construction of the person and in context analysis. Likewise, the fact that initially few teachers recognize the role of psychological, behavioural, and cultural expressions, shows in them epistemological perspectives typical of modernity, which favour logocentric ideals, the reason-emotion opposition, and the suppression of the body (García, 2020).

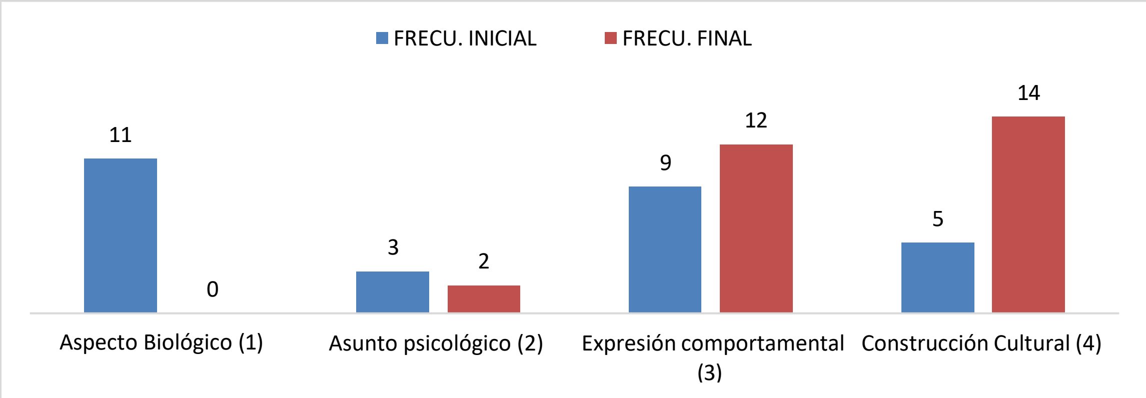

Figure 1. Frequencies of the conceptions of teachers in training on the relationship between the teaching of Sexuality and Science Education.

These results show that, after the didactic intervention, the teachers in training have mobilized their positions on sexual education; towards reflective and critical tendencies based more on sensitive reason than on instrumental reason (Mosquera & García, 2021); evidencing the need to train from a biopsychosocial perspective in an open and relevant dialogue from the recognition of the interests of the student body, the particularities of the context and the training needs.

Conceptions of teachers in training about the teaching of sexuality

Before the didactic intervention, most of the teachers in training presented biologist and prevention and promotion conceptions about the teaching of Sexuality. After the intervention, most of them showed conceptions about said teaching related to socio-scientific phenomena and health education (Figure 2).

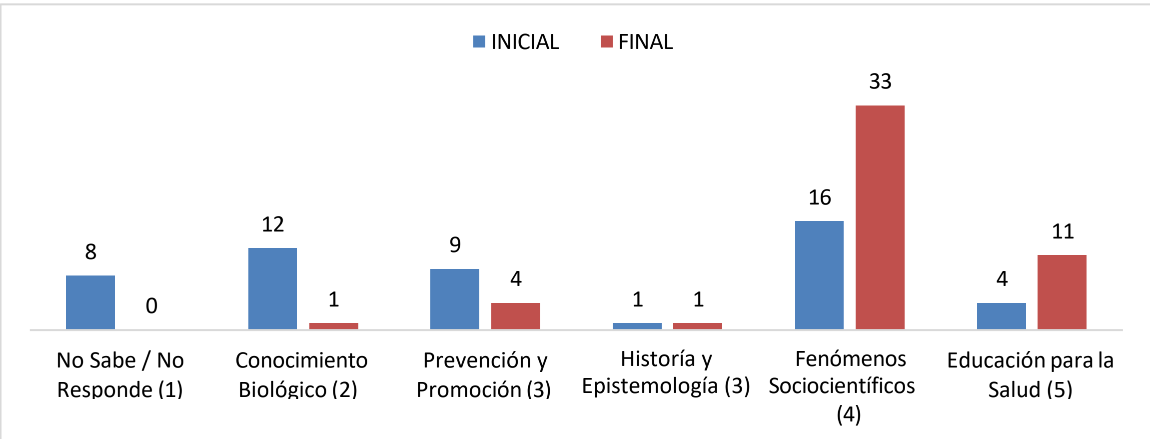

Figure 2. Frequencies of the conceptions of teachers in training about teaching sexuality before and after the didactic intervention.

The t-student showed significant differences for the subcategories Education for Health (p=0.041), Sociocientífico Phenomena (p=0.001), and Biological Knowledge (p=0.001), thus, the didactic intervention achieves that teachers conceive the teaching of sexuality from a biopsychosocial perspective (Viana de Abreu et al., 2019). The non-significant difference in the Promotion and Prevention subcategory (p=0.133) shows that teachers who associate the teaching of sexuality only with topics of reproduction, prevention of pregnancy and sexually transmitted infections (STIs), or sexual diversity as speciation; They do not change their position, perhaps because the "normal" is the emphasis on these issues with a biological- hygienist approach (Grotz et al., 2020; Soares & Gastal, 2016).

Thus, after the didactic intervention based on CSC, the trainee teachers consider it important to include in science teaching aspects such as the historical and critical analysis of how scientific research has been permeated with issues such as the myth of the neutral male scientist. mainly, the recognition of the role of women and non-heterosexual people in scientific production (Morgade et al., 2016).

Conclusions:

The didactic intervention using CSC significantly changes the conceptions of biology teachers in training, about the teaching of sexuality, from eugenic biological approaches, towards biopsychosocial models; although clinical-preventive positions persist, perhaps because of the emphasis they "normally" have had in traditional teaching. These results show the need for teacher training, in Health Education, and the dialogue between biological, social, economic, political, and affective knowledge.

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I try to encourage my students to think, read, and talk science - Intelligible identities in university teachers' figured worlds of higher education biology

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Rationale and theoretical background

Higher education biology is often imagined, perceived, and described as having reached gender equality in terms of who gets to participate in disciplinary practices, and thereby as more accessible and also easier than other natural science disciplines (Wong et al., 2022). Biology is thereby constructed to be the most inclusionary university natural science field, within which gendered processes of exclusion are absent and equality along the axis of gender has been reached. In contrast to for instance physics, a male dominated natural science discipline that is given extensive attention in science education research, qualitative explorations of higher education biology are rather scarce and marginalized. This marginalization has been critically discussed to be a consequence of the assumption that equality can be measured quantitatively, based on female biased undergraduate enrolment (Grunspan et al., 2016). Women and other minoritized groups are, however, still strongly underrepresented in natural science landscapes (UNESCO, 2021) in general and greatly outnumbered by men among biology faculty in, for instance, Sweden (SCB, 2020) and the United States (Sheltzer & Smith, 2014). Biology is consequently *not* excepted from common patterns of a decrease of women's participation in the natural sciences along the academic career ladder and finds itself in a disciplinary STEM hierarchy (Wong et al., 2022). Amongst other systemic processes, and understanding learning as a sociocultural process, reproductions of exclusionary norms of being in and doing science have been described as contributing to making a sense of belonging to science practice accessible for some, but less so for others along intersecting axes of power (Avraamidou, 2020).

We build our theoretical framework on the understanding of all social productions to happen in discursive social and cultural constructed figured worlds "in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others" (Holland et al, 1998, p. 52). These worlds, like higher biology and science education, as contexts of meaning or cultural realms, are peopled by collective imaginaries and thereby "take shape within and grant shape to the coproduction of activities, discourse, performances, and artifacts" (Holland et al., 1998, p. 51). Gee (2014) describes figured worlds as simplified imaginaries and "typical stories" that vary between people with different social and cultural backgrounds (Gee, 2014, pp. 174–175). With this understanding, we both explain the currently constructed intelligible ways of being and doing biology, which are interconnected with intelligible gendered performances (Butler, 2006) but also allow for possibilities of cultural change.

Key objectives

In this study (Authors 2023) and building on a similar study on biology students (Authors 2021), we explored how higher education biology teachers negotiate norms of doing and being in science through the lens of science identity. We asked, what higher education biology identities (for teachers and students) are imagined as (unintelligible by university biology teachers and thereby get (re)produced in higher education biology landscapes and cultures.

Research design and methodology

We collected and analyzed 94 teaching statements written by university teachers when applying for faculty positions. We argue that in and through teaching statements, university biology teachers negotiate and perform overarching academic, scientific, and disciplinary norms and discourses with the goal to present themselves as intelligible candidates for the respective academic position. These statements thereby become performative and can be considered as statements of value, which display implicit and explicit identities recognized in worlds of higher education biology as well as norms that render those identities (un)intelligible. With this understanding, we explore both normative reproductions as well as alternative productions and imaginaries that transgress circularities of exclusive science and biology practices. Merging cultural, social constructivist, as well as feminist critique of science perspectives, we used a discourse analytical framework (Gee, 2014) with a sensitivity towards possible identities and in the following describe two synthesized higher education biology teacher identities deriving from the analysis of the teaching statement texts.

Findings

We identified two university teacher identities imagined as intelligible: Research Science Teachers and Facilitating Science Teachers. *Research Science Teachers* position research and associated masculine-coded competences as anchor points of biology practice. They consider researchers to be ultimate knowers and consequently to be best suitable for university teaching with the goal to recruit students into research. *Facilitating Science Teachers*, even though aware of the hegemonic position of research, disentangle imaginaries of what makes a researcher from what makes a university teacher. They understand themselves to be facilitators for students' learning and in interaction support them in the process of aspiring their goals. They thereby transgress dominant imaginaries of research as the ultimate competence for themselves and students, and create spaces for alternative identity work.

Conclusions

Visualizing the centrality of a masculine coded research competence imaginary that is also connected to hegemonic imaginaries of science as elite, this study provides further evidence that norms of masculine-coded science practices are positioned as anchor points in university biology teachers' identity negotiations and hence biology as a discipline to not be a gender-neutral practice. While research on possible and impossible (science) identities in male-dominated natural science disciplines is rather extensive and perspectives on higher education biology marginalized, our explorations point toward broader mechanisms of in- and exclusion, based on imaginaries of who embodies science in identity political and gendered fields of tension (Brickhouse et al., 2006).These findings contribute to a more nuanced understanding of (re)productive processes in science education, providing perspectives of how to together transgress intergenerational (re)productions of hegemonic norms of doing science. Additionally, this study provides further evidence that higher education biology is not a gender-neutral higher education landscape and shed lights on realms of the reproductions of exclusionary norms rendering certain identities unintelligible in higher biology education.

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Social justice and school biology education: What can and should be taught about gender issues?

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Theoretical background or rationale
There has been a long debate within science education as to the aims of school science (e.g., Mansfield & Reiss, 2020). Some science educators have advocated a more 'scientist-oriented' curriculum, concentrating on funnelling capable students into science and engineering while at the same time enhancing understanding of the central ideas about the nature and practices of science. Others have argued for a more humanistic school science, focussing on the ways in which science education might contribute to social justice and democratic ideals. The argument that school science should contribute to social justice has gained much traction over the past two decades (Rodriquez, 2015).

Key objectives:
An important way in which the aims of science education are conveyed to new teachers is through initial teacher education (ITE). We therefore sought to gain the views of a sample of university tutors responsible for secondary science education about whether, and if so how, school science might contribute to social justice. In this talk our focus is on biology education, specifically on issues to do with gender. Interviewees were asked where in school biology they thought that social justice issues might be addressed, whether there are any issues to do with social justice that are particularly relevant for people of different genders, and whether they thought that school science could play a role in teaching about issues to do with social justice that are particularly relevant to people of different genders.

Research design and methodology:
We adopted a qualitative research design using individual, semi-structured interviews. Semi- structured interviews met our objectives in that they are highly purposeful tasks where the researchers serve as instruments and data are co-constructed by the researcher and the participants (Merriam & Tisdell, 2016).

Twelve university tutors at universities with secondary science ITE cohorts within England participated in the interviews from March to June 2022. Four had a specialism in biology, four in chemistry and four in physics. Each came from a different university, with a range of universities chosen with respect to location, academic standing, history and student diversity. Each interview lasted about 30 minutes. Interviews were undertaken, after receiving research ethics approval from our university, by the same person (one of the three authors) using Microsoft Teams and were audio-taped and transcribed. The transcripts were repeatedly read and thematic analysis used to identify major themes.

Findings:
One interviewee had almost nothing to say in response to the questions: "My first thought is blank. I suppose where my mind is going in terms of gender, it's looking at access to science and influence on actually dictating policy on science and such like. So, it's … yeah, I mean, physics degrees are generally very male-oriented". Another interviewee said "I think we've made great strides with the gender issues. I mean there are gender inequalities, as you know, obviously these due to physics has got its women into science and actually more schools now have their women into science posters at some point … in terms of teaching, no, I don't think science teachers would want to go down that road. I actually don't think they ought to go down that road either; it's a minefield".

However, all the other interviewees had much more to say and were positive about the role that school biology could play with respect to social justice. Our findings are reported under four themes.

Girl-friendly science
There was no enthusiasm for what might be termed 'girl-friendly science' with one interviewee stating "when I was a teacher many years ago, we used to debate whether we should do things like cosmetics for girls and I think that's patronising actually" and another arguing "I absolutely don't think that you should talk about washing machines and things in physics, you know, rather than cars. I really, really don't".

Issues to do with discrimination and access

A frequent theme was 'issues to do with discrimination and access'. As one interviewee put it: "the world is very male-dominated and leadership across the world and yes, so I would say that those social justice issues are very noticeable when you see the EU leaders or the NATO leaders, that most young women may see the world as not being something where they have particular power … I think that's true within science as well, that if you look at images of science and scientists, although I think it's got better, it still looks like it's a very male-dominated profession".

Issues of representation

Allied to issues to do with discrimination and access were 'issues of representation'. As one interviewee said: "we all know that there have been many successful women scientists from minority ethnic groups etc, who have been really successful. But they're not the ones that you see on the billboards". Another said: "let's research all these, let's look at Mary Anning, let's look at [Caroline] Herschel and the question is, why don't we know about these people, what's going on here and why?".

Gender, sex and reproduction

When it came to particular areas within the biology curriculum where interviewee thought that social justice issues to do with gender might be addressed, many interviewees unsurprisingly talked about topics within 'gender, sex and reproduction'. One interviewee said: "So the first thing that strikes me is around gender diversity and not pigeon holing into two genders and so particularly non-binary people and trans people … So that's a massive issue for social justice because we know that that has real devastating and deadly impact for people in their lives".

Conclusions:

The large majority of the interviewed university tutors were positive both about the importance of social justice issues in science and of the potential for these to be addressed in school biology, including in relation to gender issues.

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Scientific thinking and mechanistic explanations

Characterizing the construction of mechanistic biological explanations among high-school students

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Theoretical background or rationale

Mechanistic reasoning about biological phenomena holds a central role within the field of biology. It involves identifying a phenomenon, recognizing its initial and final conditions, identifying involved entities and their activities, and arranging them logically (Russ, 2008). In recent years there has been a growing emphasis on cultivating this skill in scientific education. Research has demonstrated that while students can formulate mechanistic explanations (Krist ,2019), this process is challenging, especially when students lack biological knowledge (Haskel-Ittah et al., 2020). The process of constructing mechanistic explanations involves a continues unpacking of black boxes; however this continues unpacking lens is missing from the literature (Haskel-Ittah, 2023). Using the lens of black box unpacking during the construction of biological mechanistic explanations can provide new insights into the dynamic process of constructing explanations.

To delve into this aspect, we adopted the AIR model as our conceptual framework. The AIR model delineates three key components of epistemic thinking: Aims, Ideals, and Reliable processes leading to the aims (Chin et al., 2014). We employed this model to examine the various ideals and reliable processes (strategies) that students encounter when constructing mechanistic explanations.

Key objectives

By characterizing those ideals and strategies, we aimed to gain insight into how students develop their explanations. Specifically we asked:

1. Which ideals and strategies do students hold regarding biological mechanistic explanations?
2. How do these ideals and strategies interplay while students construct mechanistic explanations?

Research design and methodology

In the context of learning about the tanning mechanism, 65 high-school students worked in groups (a total of 16 groups). We prepared a set of 17 'black box' cards, each containing a question representing black boxed mechanistic parts within the tanning mechanism and their unpacked mechanism on the opposite side. Students were asked to review all the cards, to choose one black box they wish to unpack and to justify their choice. After reading the information on the other side of the card, they were asked to explain the tanning mechanism and to evaluate their explanation (what is good and what is missing from it). This process was repeated 4 times (4 chosen cards).

Using a bottom-up approach, we identified students' sequence of unpacking, strategies and ideals that emerged accordingly from students' choices of black box cards, justifications and evaluation of explanations.

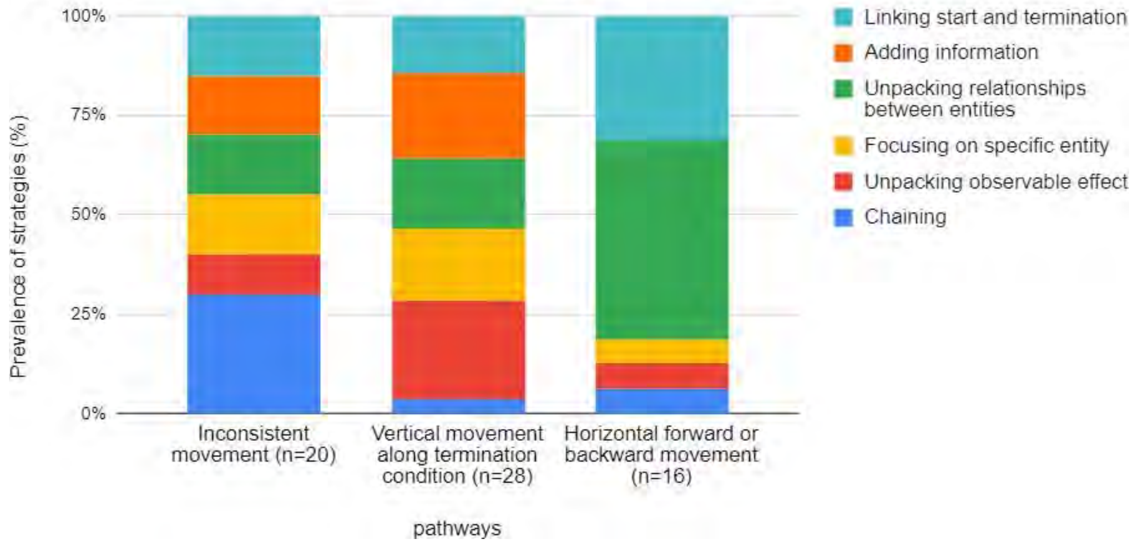
Findings

Analyzing the sequence of unpacking led to the identification of three pathways in which the students acted: Horizontal forward or backward movement, Vertical movement along termination condition (moving along levels of organization) and Inconsistent movement.

Employing a bottom-up coding approach for students' strategies which led to specific pathways, resulted in the identification of six strategies employed by students when constructing mechanistic explanations: Adding information without a specific purpose, Linking between start and termination conditions, Unpacking observable effect, Unpacking the relationship between entities within the process, Focusing on a specific entity and Forward and backward chaining.

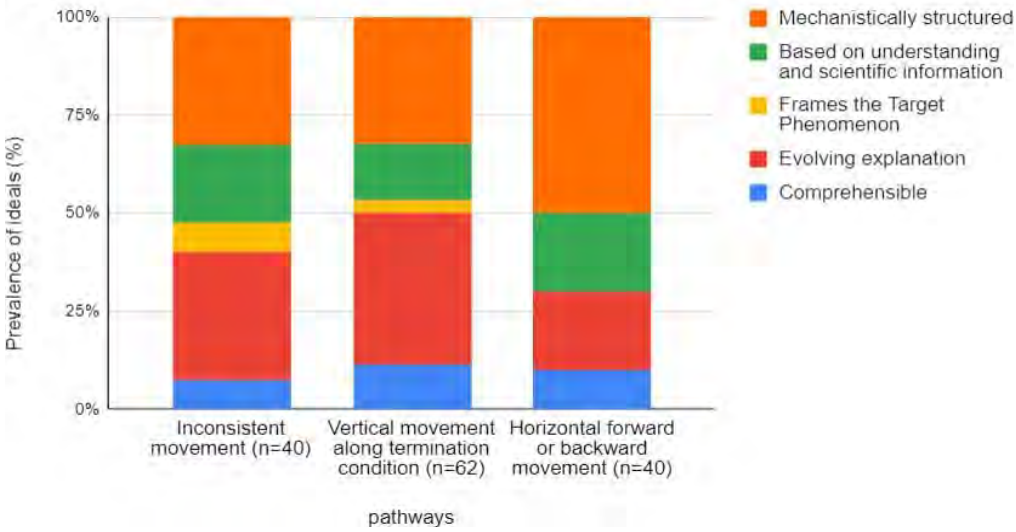
We recognized that in each pathway the distribution of strategies was different. The main strategies used in the horizontal pathway sequence of unpacking were unpacking the relationship between entities and linking between start and termination conditions. The main strategies which characterized the vertical pathway were unpacking observable effect and adding information. The main strategy that guided the inconsistent movement sequence of unpacking was chaining (Fig 1).

Fig 1. The distribution of strategies in relation to the progress paths of the students



By analyzing students' evaluation we identified five ideals for mechanistic explanations. Some were mechanistic-related ideals: Framing the target phenomenon or Mechanistically structured. Others were not mechanistic-related: Based on understanding and scientific information, Comprehensible, Evolving.
We assessed the distribution of different ideals across the various pathways and recognized that in the inconsistent and vertical pathways the central ideals were that a good explanation is an evolving one and that a good explanation is mechanistically structured, while in the horizontal pathway the central ideal was that a good explanation is mechanistically structured (Fig 2).

Fig 2. The distribution of ideals in relation to the progress paths of the students



Conclusions

High school students construct mechanistic explanations while moving along explanatory black boxes using different strategies. Mechanistic strategies such as chaining or unpacking the relationship between entities directs towards horizontal or inconsistent pathways, while the use of non-mechanistic strategies leads to a vertical pathway that focuses on moving along biological levels of organizations at the termination conditions. Student's ideals for a good mechanistic explanation includes mechanistic ideals alongside other ideals. It seems that students who mainly hold mechanistic ideals can progress in a more orderly and systematic manner in the construction of their mechanistic explanation. These results might indicate that having non-mechanistic ideals can influence students choice of strategies and tilt their choice from mechanistic strategies to less mechanistic strategies.
The presence of mechanistic ideals in all pathways and the absence of corresponding mechanistic strategies in some, can also indicate that the understanding that a mechanistic explanation should have mechanistic characteristics does not indicate the ability to employ mechanistic strategies.

Therefore, to effectively enhance mechanistic reasoning among students, it is essential to attend to how they evaluate a well-constructed mechanistic explanation and provide them with the necessary tools for evaluation and construction of such explanations.

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Who's afraid of the big black box? Promoting students' discussion of black boxes- affordances and constraints

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Keywords
mechanistic reasoning; explanations; epistemic goals; nature of science

Background

Utilizing the new mechanical philosophy (Machamer, Craver, & Darden, 2000), we acknowledge that mechanistic explanations primarily comprise entities and their activities. However, such explanations also encompass black boxes, which are informational units with missing mechanistic knowledge. As Biology is a discipline spanning over multiple organizational levels, all mechanistic explanations in Biology include black boxes. Such black boxes can stem either from acknowledging lack of knowledge for their unpacking, but also from acknowledging that their unpacking will not add any explanatory power to a specific explanation (Author, 2022). As an example, acknowledging Punnett squares as a black box explanation was an important step towards locating the identity of the gene entity in the beginning of the 20th century (Morgan, 1909). However, today, acknowledging Punnett squares as a black box explanation is an important step in considering the explainer's goals and audience's understanding (Authors, 2022; Gericke & El-Hani, 2018; Nathan, 2021, pp.
34–37).

While scientists appreciate explanatory black boxes, studies hint that teachers rarely expect students to reason about them. For example, Tang, Elby & Hammer (2020) have demonstrated that teachers view young students as lacking knowledge to ask meaningful questions about black boxes' content (the mechanism). Furthermore, teachers tend not to address the functionality or goal of an explanation and usually hold the notion that good explanations should be as comprehensive as possible (Justi & Gilbert, 2002). However, we have previously demonstrated that even *without* presenting students the explicit black box term, students are able to appreciate explanations we identified as either black box explanations or unpacked mechanistic explanations. Furthermore, they link the former to prediction and the latter to phenomenon description and manipulation (Authors, 2022).

Considering the above, it became of interest to us to investigate both the affordances and constraints of familiarizing students with the idea of black boxes as an abstract yet explicit term. We were especially interested in learning how students use the contrasting terms of 'mechanism' and 'black box' to reason about information they include or omit from their explanations. Additionally, we were interested in learning what constrains students from using them as part of their reasoning.

Methodology

We designed a 24-hour biology course for 10th graders, focusing on cancer development mechanisms while introducing the explicit term of black boxes. The course exemplified the idea of identifying black boxes in mechanistic explanations and unpacking them. Following, twenty-three biotechnology students were instructed to create a disease-related informational poster. Students were handed worksheets asking them to identify at least one unpacked mechanism and one black box in their poster and rationalize their decision to unpack or black- box accordingly. We recorded group discussions and analyzed recordings, worksheets and posters. These were scanned for the use of 'mechanism' and 'black-box' terms in the context of information inclusion or exclusion.

Findings

We first acknowledge finding several unconventional uses of the unpacking term. Students sometimes referred to unpacking a mechanism as:

1) Naming the mechanism or the phenomenon.
2) Discussing the input and output of the phenomenon.
3) Discussing <u>any</u> missing detail.
4) Adding an entity, while not promoting the ability to explain the passage from input to output.

Nonetheless, as students used the terms more conventionally, we were able to recognize three main categories by which they rationalized use of mechanistic information: Schooling, setting epistemic goals, nature of science. Table 1 summarizes the main categories and matching justifications.

Justification Category	Justification	Used for
Schooling	Enlarging the quantity of words in the text.	Justifying unpacking
	Focusing text on what the teacher considers as noteworthy.	Justifying both unpacking or black-boxing
Setting epistemic goals	Supporting in hiding confusing details.	Justifying black-boxing
	Supporting in hiding uninteresting details.	Justifying black-boxing
	Adding interest.	Justifying unpacking
	Focusing reader on salient features.	Justifying both unpacking or black-boxing
	Adding explanatory power.	Justifying unpacking
Nature of science	Supporting students' lack of mechanistic knowledge.	Justifying black-boxing
	Conforming to the idea that an explanation in Biology contains an unpacked mechanism.	Justifying unpacking

Table 1: Students' justifications for unpacking or black boxing information

Conclusions

Data reveal that faced with the 'mechanism' and 'black box' terms, some students were less able to use the 'mechanism' term conventionally. This was one hurdle constraining students from discussing their unpacking of mechanistic details. Furthermore, even with students who used the terms conventionally, we observed students who used them to discuss less "thought provoking" rationalizations which correspond with non-etiological reasons as discussed by Trommler et al. (2018). However, some were able to discuss how unpacking or black-boxing serve their epistemic goals or conform to ideas of nature of science.

Such conclusions point to the possibility of another dimension of discussing mechanistic reasoning in the biology classroom, which is the identification of black boxes and the formation of a discussion concerning the necessity of their unpacking in the formulation of mechanistic explanations. Implications for this are not only extending mechanistic reasoning beyond rote learning, but also for creating opportunities for students to shape the knowledge building work in their classroom and thus become epistemic agents in it (Miller et al., 2018). While our study shows that students may need support in defining what unpacking means,

this understanding can assist in empowering students' ability to discuss the power of unpacked mechanisms as well as the power of black box explanations.

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Complexity and non-knowledge as a challenge – is there a tendency to prefer linear explanations?

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Theoretical background or rationale

Instructional explanations are an important part of teaching, and they not only communicate content on biological phenomena but also introduce students to appropriate explanations of the discipline (Larreamendy-Joerns & Muñoz, 2010). For this reason, research on instructional explanations should also reflect on the characteristics of subject-specific explanations as they are described in philosophy of science.

Taking this perspective into account, there is an interesting contradiction between biological explanations in science and instructional explanations in biology class: Biologists are often confronted with complex phenomena (Mainzer, 2008; Potochnik, 2013). The explanations are, among other things, multi-causal, include various interactions between factors and contain non- knowledge or uncertain knowledge (Kampourakis & McCain, 2020; Wehling, 2008). Instructional explanations, on the other hand, often rely on linear cause-and-effect relationships that only address known causal structures (Jacobson & Wilensky, 2006; Potochnik, 2013).
There are several challenges in dealing with complex explanations in the classroom: There are considerations that stating non-knowledge can lead to a loss of trust in science (Wehling, 2008) and teachers aim for clarity (Krüger et al., 2013). With regard to the understanding of complex systems a tendency towards a “centralized mindset” – the tendency to attribute all effects to a central cause – is described. For complex systems, however, a “decentralized mindset” is required, in which many factors and their interactions bring about the phenomenon (Jacobson & Wilensky, 2006).

Concerning current issues (climate change, covid-19-pandemic), the acceptance of complexity and the communication of non-knowledge seems crucial.

Key objectives:

Given the relevance and the challenge, the study focuses on the differences and difficulties of explaining complex phenomena. Therefore, the following research question is addressed: How do ratings and their justifications differ between linear and complex instructional explanations?

Research design and methodology:

A computer-based questionnaire was developed for the study, containing six video vignettes of instructional explanations. The explanations vary systematically in their degree of complexity. Three of the explanations reduce the phenomenon to a single cause (linear explanation). The other three explanations present a complex cause-effect relationship and point to non- knowledge and uncertain knowledge (complex explanation). The variation was discussed in an expert group and validated in interviews.
During the questionnaire, the explanations are rated in terms of their quality by four different status groups: pupils (N=134), teacher students (N=51), teachers (N=34) and didacticans (N=31). During the questionnaire, the participants first give an overall rating for each explanation (six-point likert-scale) and can then justify their rating in an open text field. The perspectives (status groups, research approaches) are analysed in terms of triangulation for a thorough understanding of good instructional explanations (Flick, 2011).

Mixed ANOVAs (AV: rating; UV: degree of complexity, status group) were used to analyse the differences in ratings between linear and more complex explanations. The justifications are analysed with the evaluative qualitative content analysis (Kuckartz, 2018).

Findings:

The following table (Tab. 1) gives an overview of the descriptive values of the rating per vignette and the mixed ANOVA results.

Table 1: Mean scores (including standard deviations) by status group and explanatory topic and variance analysis with mixed design.

Subject area	Genetics		Ecology		Physiology	
Degree of complexity	linear	complex	linear	complex	linear	complex
Status group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Pupils (N_{max} = 122)	2,01 (0,76)	2,30 (0,74)	1,84 (0,81)	2,00 (0,85)	2,04 (0,72)	2,15 (0,79)
Teacher students (N_{max} = 51)	1,88 (0,81)	2,22 (0,86)	1,87 (0,89)	2,14 (0,75)	2,09 (0,81)	1,88 (0,68)
Teachers (N_{max} = 34)	1,98 (0,58)	2,38 (0,98)	2,20 (0,77)	2,64 (0,95)	2,28 (0,75)	2,06 (0,88)
Didacticans (N_{max} = 31)	2,01 (0,87)	1,88 (0,77)	1,99 (0,69)	2,33 (1,05)	2,06 (0,82)	1,90 (0,75)

ANOVA	*df*	*F*	η^2	*df*	*F*	η^2	*df*	*F*	η^2
Degree of complexity	1	8,51**	0,04	1	11,96**	0,05	1	2,47	0,01
Status group	3	1,39	0,02	3	5,25**	0,07	3	0,72	0,01
Complexity x Status gr.	3	2,71*	0,03	3	0,74	0,01	3	2,08	0,03
Residuals	229			226			222		

Note: N_{max}: Due to missing values for individual videos, the calculations per status group are based on the maximum number of people.; *M*: mean; *SD*: standard deviation; ANOVA: Analysis of variance with mixed design; *df*: degrees of freedom; *F*: F-value; η2: partial eta square; *: $p \leq 0{,}05$; **: $p \leq 0{,}01$.

There is a significant interaction effect for the explanations on genetics – the linear variant is rated better depending on the status group, didacticans are the only group to rate the complex variant better. For the explanations on ecological phenomena, there is a significant main effect – all groups rate the linear explanation variant better. There are no significant differences in the evaluation of the physiological explanation – only pupils tend to prefer the linear explanation, while all other status groups prefer the complex explanation.

The following reasons can be reconstructed: Across all status groups, a vagueness of complex explanations is evaluated negatively, whereas the identification of gaps in knowledge does not lead to uncertainty. While teacher students and didacticans evaluate the explicit mention of non-knowledge and uncertain knowledge positively with reference to the nature-of-science, for teachers it seems to contradict the goal of knowledge transfer. Pupils don't refer directly to non-knowledge, but it seems that visualisations are gaining importance for their understanding of complex explanations.

Conclusions:

On the one hand, the different judgements imply a need for teacher training to ensure that non-knowledge is not seen as a contradiction to the communication of knowledge through instructional explanations but as a normal characteristic of the discipline (Kampourakis & McCain, 2020; Wehling, 2008). On the other hand, the results indicate that pupils can be encouraged to deal with non-knowledge which also has a political relevance in times of global polycrises.

Further research should address how to visualise complex phenomena in a structured and comprehensible way.

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Incomplete biological explanations in the media and its impact on laypeople's understanding

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Theoretical background or rationale
The ability to search, select, and interpret scientific information in the media is an integral component of scientific literacy (Höttecke & Allchin, 2020(. Despite the wealth of literature detailing the definitions and components of scientific literacy, there is a lack of practical guidance on how to develop students' ability to deal with scientific information that appear in the public media (Feinstein, 2011).
Among other means, laypeople consume scientific information in the public media. Such information often includes mechanistic explanations. Mechanistic explanations are central in science and are important for laypeople's ability to understand and evaluate scientific information (Koslowski, 1996). Mechanistic explanations contains entities and activities whose interaction underlie natural phenomenon (Russ et, al., 2008, Craver & Darden, 2013). Even within the scientific community, these explanations are often incomplete, meaning they include gaps that are unknown to science or irrelevant to the purpose of the explanation (Craver & Darden, 2013, Authors, 2023). In a previous work we found that these gaps, in the form of black boxes, often appear in media reports on biological mechanisms (in preparation). Black boxes could be manifested in two ways:
Implicit Black Boxes: specific parts of a mechanism are obscured by filler terms such as "make" or "cause". These filler terms imply causal relationships without specifying biological activities.
Hidden Black Boxes: parts of the process are omitted from explanations.

Key objectives:
Considering that these black boxes are prevalent in biological information presented in the media, we should explore their effect on understanding in order to prepare our students for using the media as a source of scientific information. Our research question was **how does incompleteness affect laypeople's understanding of mechanistic explanations?**

Research design and methodology:
A semi-structured interview was conducted for 18 undergraduate students. Each interviewee read three mechanistic explanations, one for each mechanism (infection, variant formation and vaccination). Each explanation included complete and incomplete parts, based on a real media report. Figure 1 shows the interview process.

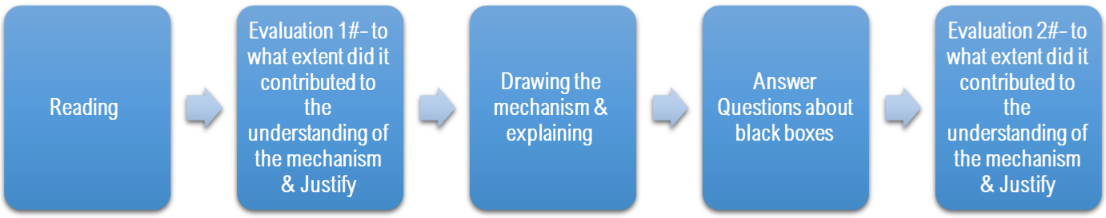

Figure 1: interview process

Findings:
Evaluating mechanistic explanations
Interviewee's evaluation of an explanation, in terms of how much it contributed to their understanding of the mechanism has changed from starting points to ending points of the interview. More importantly, their justification for why a specific text contributed to their mechanistic understanding have changes. At first, most interviewee claimed that their familiarity with biological terms that appeared in the text affected their understanding of the mechanism. Once they were required to draw mechanistic explanations, their justifications for evaluating the explanation section became different. The two justification that related to the mechanism (understanding the steps by which cause to effect are linked and understanding how step in the mechanism occurs) increased in value so that more emphasis was placed on justifications related to the mechanism and the gaps it included rather than scientific terminology and amount and elaboration of information (table 1).

	Familiarly with scientific **terminology**	**Amount and elaboration** of information	Understanding the steps by which **cause and effect are linked**	Understanding **how** each step in the mechanism occurs
Evaluating the reading section I: (n=68)	32 (47%)	12 (18%)	9 (13%)	15 (22%)
Evaluating the reading section II: (n=57)	11 (19%)	2 (3%)	13 (23%)	31 (54%)
Examples	*"I don't understand some terms. What is viral protein? "*	*"It's detailed, there's more information here"*	*"I feel like there are jumps that aren't explained"*	*"How do viruses exit from cells?"*

Table 1: Justifications for the evaluation of the text's contribution to one's understanding of the mechanism

The effect of black-boxes on laypeople's understanding

Interviewees were asked about gaps in their drawing or their explanation. For example, a question about implicit black box: "What does it mean when a viral protein is *produced*? What is happening during this process?" An example for a question about a hidden black box: "you said that a cell includes viruses, how from this stage you get to many viruses in the body?" We identified three types of answers that emerged in response:

Lack of knowledge - when there was no answer to the question that reveals a gap. The interviewee simply said "I don't know" without adding any further information.

Rephrasing - interviewee rephrases the question that was asked; a question that includes a filler term (explicit black box) or a question that doesn't includes a filler term (hidden black box) and an answer with a filler term. For example:

"Interviewer: What does it mean that it activate the immune system? Omer: The immune system responds to the protein"

In this example, Omer who was asked about the filler term "activate", rephrased it by using the filler term "responds".

Mechanistic answer - interviewee tried to unpack the black box and explained parts of the mechanism by adding additional information about entities and activities. For example: *"Interviewer: The viral protein activates the immune system. What does it mean that it activates it?"*

Neta: It's possible that some kind of stimulus was created. .. I guess the body recognizes that there is some foreign factor that needs to be dealt with and then it activates its systems, maybe white blood cells, so that it won't be there".

From our data it appears that when asked about a hidden black box, the interviewees predominantly offer mechanistic answers (12 Out of 17). Conversely, when asked about an implicit black box, the interviewees primarily respond by rephrasing (44 Out of 65).

Conclusions:

At their first intuition, laypeople think their lack of understanding of mechanistic information is due to their unfamiliarity with biological terminology. Once they try to explain the mechanism – they find the gaps. These gaps can be left as gaps, filled with filler terms or filled with mechanistic explanation. It's important to teach students how to be aware of the gaps but not to be frustrated about them – see them as the limitation of the explanation.

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Students' conceptions and conceptual reconstruction 2

Beyond Pen-and-Paper: Challenges and Potentials in Capturing Students' Conceptions by Using the Digital "Draw" A Biologist-Test

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Theoretical Background

Science education research has shown that students come to the classroom with certain conceptions about science and scientists (Miller et al., 2018). Images of scientists are examined in the field of Nature of Science-research (McComas & Clough, 2020). The stereotypical conception of a scientist often identified in studies is that of a middle-aged to elderly scientist wearing a lab coat and glasses and conducting experiments alone in a laboratory (Miller et al., 2018). However, it is questionable if it might be worth assessing more specific conceptions such as students' conceptions about biologists and their work: Scientists in biology regularly need to consider ethical norms and values (Köchy, 2008), which influence their practical work. Also, in biology the prospect of scientific work with living organisms in their habitats may be more attractive to pursue a scientific career. It is conceivable that many students might not imagine the laboratory as a place where they would like to spend their working day regularly. The Draw-A-Scientist-Test (DAST) has often been used to capture conceptions about scientists and is thought to capture conceptions efficiently and validly without requiring respondents to have written language skills (see Chang et al., 2020). However, this has been increasingly questioned in the literature. A lack of drawing skills–even among older students up to adults– may contribute to the difficulty of interpreting the drawings (Reinisch et al., 2017). One way to overcome this problem could be using technology-based tools such as the web-based software Pixton, which is used in this study. Additional potential lies in the simultaneous collection of multiple data types (e.g., drawings and recordings of students' voices), which can provide rich data sources for diagnosing students' conceptions (Chang et al., 2020).

Key objectives

This study aims to investigate whether a digital version of the DAST, which does not require drawing skills, can be validly used to interpret students' visualized conceptions. We investigate
(a) the technical difficulties students encounter when performing the task using Pixton. Since the drawing tool is available in English, we further investigate (b) the linguistic challenges that non-native-English speaking students face when using the software.

Methods

Students' conceptions about biologists and their work were assessed (Fig.1). Pixton was used to create individual pictures. Thirty-one students from three different schools ($n_{grade6/7}$=21; $n_{grade11}$=10; random sample) were prompted to create at least one picture representing their conception of biologists while working. To identify technical and linguistic difficulties during the image creation with Pixton, the students were asked to think aloud in addition to the collection of ideas. All activities were recorded via screencast. Data were processed by transcribing students' utterances and embedding all other data (e.g., Screencast) in MAXQDA.

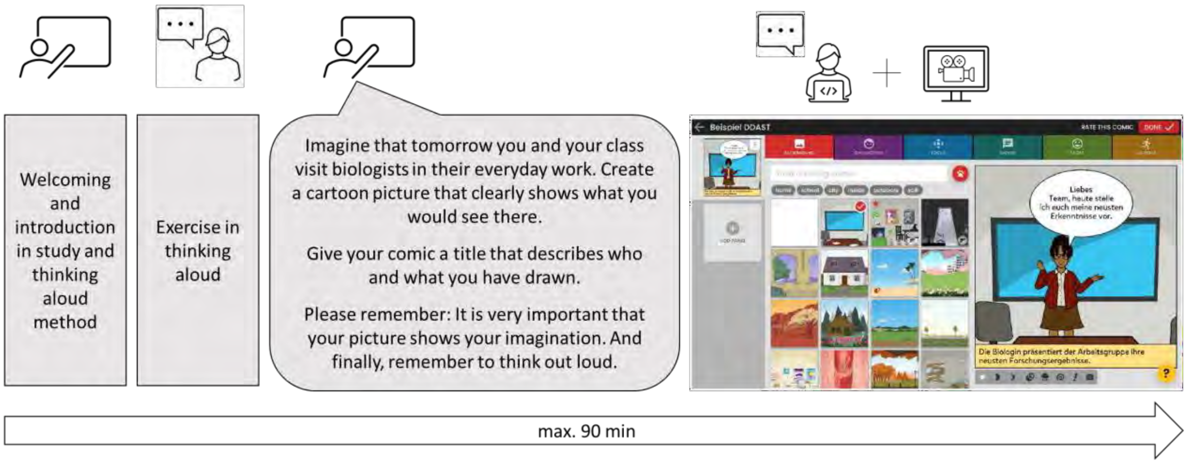

Fig.1. Procedure of the interview

Qualitative content analysis for category development was employed. Students' difficulties while creating the picture were coded to either existing categories (initially: 'technical difficulties', 'language difficulties') or new categories. After three rounds of coding by two researchers, subsequent discussions, and refinement of the category descriptions, a Cohen's Kappa of .64, was calculated indicating good intercoder agreement. One researcher then carried out the final coding.

Findings and Discussion

Almost all students had technical difficulties (a). Out of 245 codes, 82 codes related to the non- intuitive design of the user-interface and 63 related to technical difficulties not related to Pixton (e.g., mouse handling; Tab.1). It can be concluded from the difficulties encountered that students should do a preliminary exercise to familiarize themselves with the software. Such an exercise could anticipate many difficulties.
Linguistic difficulties (b) were rare and could be solved by translating a single word. In larger survey formats a dictionary could be provided.
The high number of codes in the inductively formed category "Difficulties regarding administration consistency" is striking (Tab.1). It should be noted that 326 of the codes refer to indications given by a test administrator without prior questioning by the students (other than as specified in the guidelines). It is possible that the students would have been able to perform without assistance. It is noticeable that the number of codes decreases with increasing grade groups. This finding may be explained by the fact that test administrators tended to give more instructions to younger students. The results gave hints about what additional instructions should be given to students.

Tab.1. Number of codes in 31 transcripts regarding the difficulties in creating the picture

Description	example quote	grade 6 (n = 10)	grade 7 (n = 10)	grade 11 (n = 11)	Σ
CATEGORY: DIFFICULTIES REGARDING ADMINISTRATION CONSISTENCY					
Function in Pixton is explained by the test administration without prior request by student.	"If you still want words … you can make speech bubbles there [shows] at Words. [s. clicks Words]"	216 (10)	122 (10)	62 (11)	395 (31)
CATEGORY: TECHNICAL DIFFICULTIES					
Technical difficulties that do not affect Pixton but whose source is clear (e.g. mouse handling, long loading time (e.g. insufficient internet connection) that irritates students. OR There is no restriction of the searched function in Pixton, but the interface is unclear (i.e. the function is not understood or found by the student). OR Difficulties with Pixton, as student is restricted regarding various changes or the implementation of own conception.	"Hm, that's annoying that it doesn't work so well with the scrolling. Ah, it works now." "Where can you make a headline?" "Can I also write something on the blackboard [which is shown in the picture]? Or can you... No."	111 (10)	34 (9)	89 (10)	245 (29)
CATEGORY: INDEPENDENT RESOLUTION OF A DIFFICULTY					
A difficulty arises, which student resolves independently.	"Can I have the (…) [clicks outfit] [s. clicks back] How? (…) Ah, here. [s. clicks add character]"	40 (9)	27 (9)	41 (10)	106 (28)
CATEGORY: LANGUAGE DIFFICULTIES					
Student looks up the translation of a word or asks the test administration.	"What is 'lab coat' in English?"	19 (9)	4 (3)	7 (5)	30 (17)
CATEGORY: DIFFICULTY WITH UNKNOWN SOURCE					
Difficulty occurs whose source is not clear.	"What shall I do now?"	3 (1)	3 (2)	1 (1)	7 (4)

Note: numbers in brackets: number of students

Conclusions

The exploration into the digital adaptation of the DAST via a web-based drawing software highlighted technical challenges for students, underscoring the importance of digital acclimation. Nevertheless, the relatively small number of linguistic barriers show potential for broader adoption in diverse linguistic settings. Introducing a digital medium to capture students' conceptions can pave the way for bypassing the limitations of traditional drawing skills. This potential is paramount, as these conceptions are pivotal in influencing students' conceptions about the field, which can subsequently impact their science-related aspirations and career trajectories (Christidou et al., 2021).

At the conference, we will not only give insights into the challenges and potentials of the developed digital instrument but also discuss the identified students' conceptions about biologist and their working field in contrast to previous found conceptions by use of the DAST.

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An exploratory study on the effects of Conceptual Change Stories on secondary level students' understanding of food relationships

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The relationship between greek biology textbooks and teachers' / students' genetic conceptions

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Theoretical background

Scientifically literate students in genetics, might successfully face emerging biological issues that arise from biotechnological advances, as future citizens. However, the presence of genetics in secondary school textbooks includes conceptual and linguistic difficulties. Textbooks are mainly the only printed source of information available for students and teachers who use them exclusively. Therefore, textbooks could influence students' learning and understanding, yet provoke alternative conceptions. Issues in didactic transformation of scientific knowledge to school knowledge, based on textbooks, could also reinforce misconceptions. The investigation of gene concept and its function into biology textbooks, as well as teachers' and students' genetic conceptions, is necessary (Gericke & Hagberg, 2007).

International interest on exploring gene concept and its function as presented in biology textbooks, has been recorded and based on five historical gene models (Mendelian, Classical, Biochemical-classical, Neoclassical, Modern). Models are defined in literature and depict the historical development of gene concept. In previous studies, content analysis showed the presence of multiple/hybrid models in biology textbooks. Conceptual diversity reported in textbooks, that describe gene function, might not be a problem when it is obvious to the reader. Moreover, it is a useful tool for scientists. However, students could form alternative conceptions about genes, as a consequence (Christidou & Papadopoulou, 2020; Gericke & Hagberg, 2010; Santos et al., 2012).

Moreover, previous literature review has shown that teachers' and students' genetic conceptions include hybrid models in their explanations on gene function. Mendelian, Classical and Biochemical model, are more frequent while there is lack of Modern elements (Tsopoglou-Gkina & Papadopoulou, 2019).

Key objectives

The research question is:

How Greek biology textbooks of secondary school and genetic conceptions of teachers and students are related to each other?

For this purpose, this study compares the presence of historical gene models found in Greek biology textbooks of secondary school with teachers' and students' genetic conceptions that are detected.

Research design and methodology

Content analysis included all Greek biology textbooks of secondary school. Direct or indirect references to gene function were recognized in these seven textbooks and thereafter, historical models were identified.

Interviews were conducted in order to explore Greek teachers' and students' genetic conceptions. 18 students of the last grade of high school, being prepared to study Life Sciences at university, and 25 biology teachers participated. These students have been exposed to all Greek biology textbooks, in which we carried out content analysis. For this qualitative research, theoretical sampling was chosen as a strategy of data collection through the interviews that were semi-structured guided by questions concerning inheritance, genetic structure and genetic processes. They were all analyzed so as to detect the presence of historical models.

Both content and interview analysis were based on historical model's classification and their epistemological-features regarding the relationship between gene structure and function, organizational level and gene function, genotype and phenotype, as well as environmental and genetic factors. Each epistemological-feature corresponds to one or more historical models, although there are some non-historical. Thereafter, these feature- variants were identified into the units of analysis and ascribed to their models.

Findings

The percentage of the occurrence of the epistemological-features recorded in Greek biology textbooks was calculated. Afterwards, features were ascribed to the historical models that they describe and it was revealed that there is conceptual variation of the representation of gene function with the simultaneous implicit coexistence of the five historical models. (Figure 1). Biochemical model is dominant in the analysis material, followed by the Classical, Neoclassical and then Mendelian model. Moreover, the Modern model is rare. It is also found that the conceptual variation is mainly due to the Classical and Neoclassical model, which appears through their unique features that exclusively describe each of them.

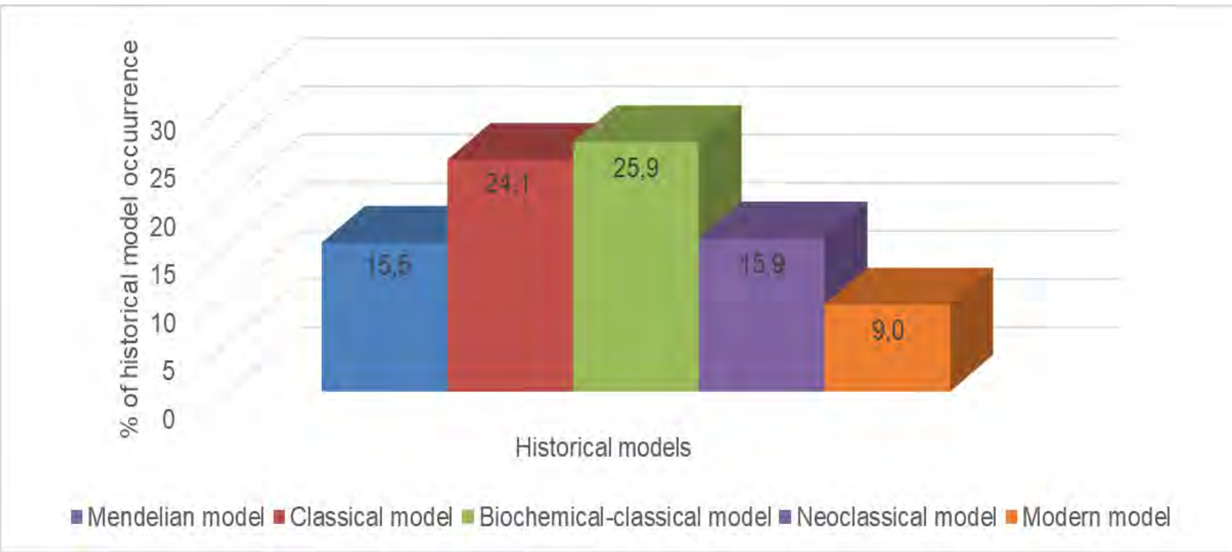

Figure 1 Occurrence of historical gene models in Greek biology textbooks.

Regarding the interview findings, despite the simultaneous presence of epistemological- features from different models in the discourse of teachers, those of Neoclassical were dominating their conceptions (Figure 2). Only about 1/3 of them are unique to this model. Features of the Modern model were also found, yet almost half of them are unique to it. Additionally, in students' gene conceptions, Classical features were more frequent, followed by those of Neoclassical and Mendelian, without being represented by their exclusives. Features of the Modern model are limited (Figure 3).

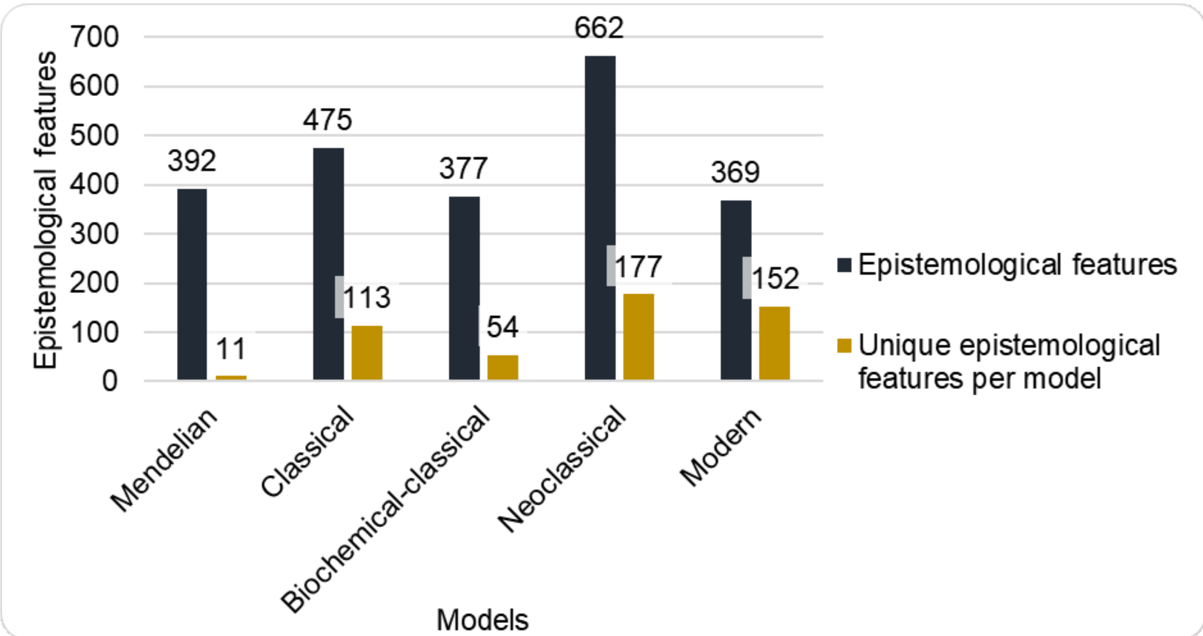

Figure 2 Number of epistemological-features found in teachers' conceptions.

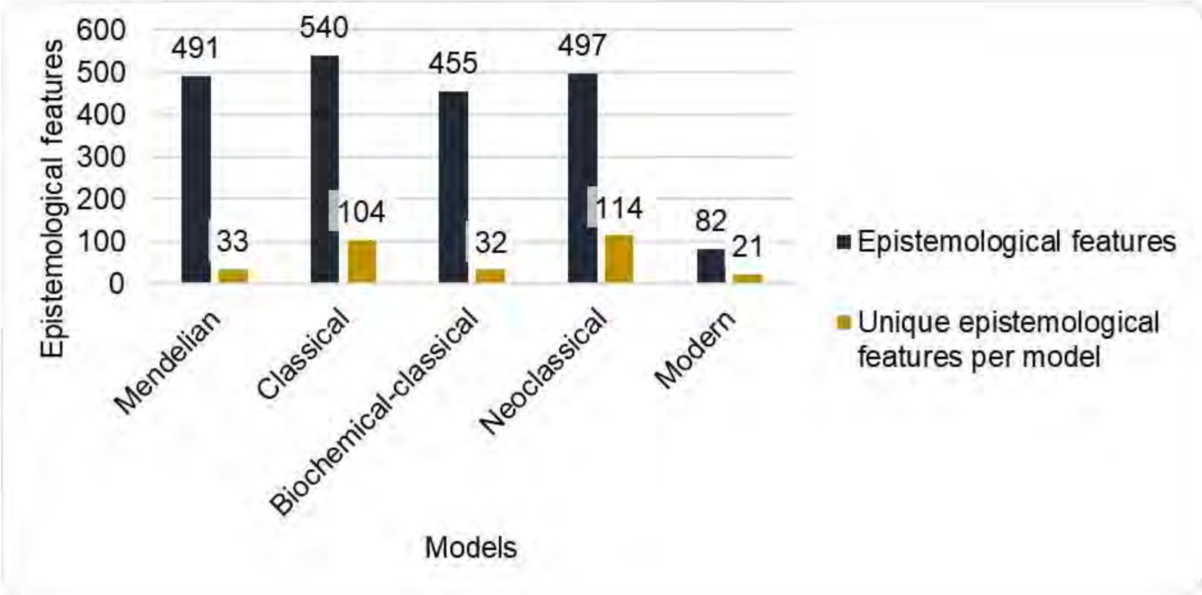

Figure 3 Number of epistemological-features found in students' conceptions.

Conclusions

It is known that the dominant Biochemical model in Greek biology textbooks contains some internal inconsistencies that might promote alternative conceptions. This model is a transition between Classical and Neoclassical model, having epistemological-features of both. Conclusively, despite the presence of multiple/hybrid historical models in Greek biology textbooks, it seems that teachers' and students' conceptions are related to those models that are presented mainly with their unique features. These are Classical and Neoclassical model, which describe more clearly gene function. In case of teachers, Neoclassical ideas are more frequent, but strong Modern conceptions are also recognized, which are probably a result from prior scientific training. Finally, students' conceptions were found to be oriented to basic-outdated Classical ideas.

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Reconstructing learning trajectories for evolution: A quantitative study using learning analytics

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Teaching biodiversity/ sustainability

Development of a butterfly identification app by students for students within the dpack model

Birgit Baumann, Jorge Groß

Theoretical background or rationale

In the context of advancing digitalization, the number of digital identification apps for species identification is growing. In these apps, species identification is carried out either by photo recognition (Mäder et al., 2021) or by graphics as multi-criteria keys (ID-Logics; Groß et al., 2018). Regarding the acquisition of shape and species knowledge competencies, several non- digital and digital identification formats have already been investigated in school practice (cf. Finger et al., 2022), but none of those identification apps have been made by students so far.

In the project ID Nature, we aim to leverage the motivational factors associated with both the creation of a product and the significance of digital media in the students' everyday live to build a fruitful learning environment. Our understanding of learning processes is based on moderate constructivism and a revised conceptual change approach; the study is oriented to the model of educational reconstruction (Duit et al., 2005). With regard to the digital knowledge and competence facets, the DPaCK model (Huwer et al., 2019) is used for analysis, which shows the intersections of three relevant areas for the design of digital education: pedagogical, content, and digital knowledge.

Key objectives:

Therefore, two research questions were derived: What learning processes can be found in connection with ESD when students work with butterflies? What is the impact of these adaptive learning environment for creating a digital identification app in terms of learners' subject- specific and digital competencies?

Research design and methodology:

The data was collected in two qualitative sub-studies: i) cognitive heterogeneity was diagnosed through the identification of students' conceptions of butterflies by guided interviews and drawings (n=6, 11-12 years, high school). By comparing the students' conceptions with scientific conceptions, we identified learning opportunities and -obstacles. ii) Identified learning processes and acquired competencies were diagnosed through interviews using the method of Retrospective Inquiry into Learning Process to capture changes in conceptions (Groß & Gropengießer, 2003) (n=8, 12-13 years high school + n=18, 11-12 years high school). Learning processes are the result of collaboration on the app: after researching about one butterfly species, the students created its profile in the CMS, looked for confusable species and assigned fitting distinctive-mark-graphics to their species. Data from both interview groups were interpreted using qualitative content analysis (Mayring, 2022) and conceptions were empirically derived.

Findings:

The interpretation of the data on students' conceptions (i) shows that students associate butterflies with colourful, patterned creatures of summer. Their conceptions are diverse concerning classification in the animal kingdom (insects), the body structure (number of legs) and the butterfly's way of life. The identified learning obstacles, like the number of legs, were taken into account by developing identification questions, distinctive-mark-graphics and explainer videos. The interviews after the project (ii) revealed that the intensive study of butterfly species and especially the selection of its suitable distinctive-mark-graphics helped the students focusing on the shapes' varieties and thus to enhance the correct recognition of species. Specific challenges in using the learning environment were identified. Regarding digital competencies, they improved their skills and awareness in internet research, copyright, explainer videos and working in a CMS. Furthermore, the assumption of the expert role and the associated responsibility led to a change in perspective for the students (Baumann et al., 2023). Also, the possibility of participation had a motivating effect for them. Furthermore, the students co-designed the app by suggestions for optimized operation and further characteristic graphics.

Conclusions:
The results of the study show that students' conceptions reveal learning obstacles that can be addressed through targeted distinctive-mark-graphics and explainer videos. The challenge remains to make the digital learning environment (CMS and accompanying materials) even more user-friendly to further expand the participation of learners. As part of the collaboration on the app design, students acquired the competence to identify determining characters. Furthermore, digitality enabled motivation through collaboration, cooperation and publishing. This enabled the students to take on the role of an expert and therefore responsibility. The DPaCK model helped to analyze the acquisition of digital competencies of the students. So, making the DPaCK model explicit for teacher action is also suitable for analyzing lessons. As a result, guidelines for teaching digital competencies were developed to use digital media in science education.

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The effects of an escape game dealing with biodiversity on student motivation in biology lessons

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Rationale

The worldwide increase in recreational escape games (EG) as well as their assumed impact on climate education and associated biodiversity loss has led educators to apply their design features to educational settings (Ouariachi & Wim, 2020; Veldkamp et al., 2020). In EG, small groups of players accomplish challenges in order to reach a certain goal within a limited time (Ouariachi & Wim, 2020). EG provide students with a collaborative game-based learning experience and are accompanied by positive effects on student motivation and learning (Fotaris & Mastoras, 2020). These positive effects can, for instance, be explained by the hints and solutions, which are given during the EG (Veldkamp et al., 2020). Moreover, EG can promote important competencies including problem-solving, communication, and critical thinking. Such competencies are important for combating climate change and biodiversity loss, which are firmly embedded in educational curricula for biology classes (KMK, 2020; Ouariachi & Wim, 2020). Measures to promote motivation and competencies in STEM subjects are especially needed, for instance, because students' motivation and competencies are decreasing or only slightly pronounced in these subjects (OECD, 2016).

While the implementation of EG increases, an empirical evaluation of the motivational and cognitive advantages is still lacking, especially in the context of climate change (Ouariachi & Wim, 2020; Veldkamp et al., 2020). The current project aims to close this research gap by evaluating the effects of the EG 'Next Exit Biodiversity' of ECOMOVE International e.V. dealing with the topic 'protection of biodiversity'. Since the protection of biodiversity is a significant social goal, it is of special importance to foster students' motivation to engage in this topic in school, outside of school, and, at best, after their school years.

Key objectives

Do students learning about biodiversity in lessons with EG have a higher intrinsic motivation than students who learn the same content without EG?

Do students who learn about biodiversity in lessons with EG acquire higher knowledge than those who learn the same content without EG?

Research design and methodology

In the first implementation of the study, 38 students (53% female; M_{age}=13.71 years; SD_{age}=0.69 years) participated. To investigate the effects of the EG on their motivation and knowledge acquisition, a pretest-posttest control group design was chosen. In the pretest, the students' intrinsic motivation in their regular biology lessons as well as their knowledge about the content of the EG were assessed. Afterward, the students participated in a two-hour teaching unit on biodiversity either in lessons with EG or without the elements of the EG (e.g., codes, time display). The content of the teaching unit was the same in both treatments. In the posttest, we assessed students' intrinsic motivation during the teaching unit as well as their knowledge with the same test we applied in the pretest. To investigate the students' intrinsic motivation during their regular biology lessons, the scales for motivational regulation in learning (Thomas & Müller, 2016; Cronbach's Alpha: α=.80) were applied. Their intrinsic motivation during the teaching unit was examined with the short scale for intrinsic motivation (Wilde et al., 2009; α=.89). The students' knowledge was assessed with a self-developed test specifically tailored to the content of the intervention. ANOVA was applied to compare the students' intrinsic motivation in both treatments. ANOVA with repeated measures was used to compare the students' knowledge acquisition in both treatments.

Findings

Students in both treatments expressed a comparable intrinsic motivation in their regular biology lessons (pretest; (F(1,36)=0.10, p=.759). After the intervention, no differences were found between the groups regarding students' intrinsic motivation during the teaching unit (F(1,36)=0.21, p=.649). Regarding students' knowledge, ANOVA with repeated measures showed no significant interaction of the factors time and treatment (F(1,36)=0.09, p=.761). However, a significant main effect of the factor time could be found with a high effect size (F(1,36)=37.48, p=<.001, η^2=.51). Students in both treatments showed an increase in knowledge regardless of the treatment.

Conclusions

Based on previous findings, it can be stated that EGs can be an important measure to promote motivation and learning in biology classes (e.g., Veldkamp et al., 2020). This is of particular importance, as students should be motivated to engage with socially relevant topics such as the protection of biodiversity, and currently rather decreasing trends are observed with regard to motivation in biology classes (OECD, 2016). Our initial results indicate no differences in the intrinsic motivation and knowledge acquisition of students in biology lessons with and without EG. However, we are not yet able to draw reliable conclusions due to the small sample size. The results of a larger sample will be presented at the conference.

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Gamification as a tool to increase species protection awareness for bats

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Theoretical background:
Raising species protection awareness is becoming increasingly important (Wolf, 2023). Bats are under strict protection and many bat species are threatened with extinction (Wieringa, 2022). With the focus on bats and their habitats, analogue, digital and hybrid gamification elements (Mee Mee et al., 2021; Mee Mee et al., 2022) are used in learning offers to increase species protection awareness for bats.
These offers provide opportunities for pre-service STEM teacher students to work with students from primary to secondary level. The teacher students develop and evaluate learning offers with biology contexts on the basis of the 5E-Model (Bybee et al., 2006). Contents are individually adapted in regard of students' gender, age and level of knowledge (Stemmann, 2019). Teacher students are supposed to gain experience in planning, implementation and reflection for their future work (Freericks et al., 2017).

Key objectives:
The primary research objective is to assess the impact of gamification elements on species protection awareness among pupils and teacher students in Germany.

Research design and methodology:
A design-based-research approach is used to collect qualitative and quantitative data and to redesign the learning offers to address more pupils in an inclusive way. Qualitative data in form of in-depth interviews with participants is used to gather insights to what extent species protection awareness can be promoted through the educational use of digital media, inclusively adapted material, and gamification elements. Focus points are habitats, awareness of endangered species (Pyhel et al., 2017) and overcoming fears in respect of bats (Prokop & Tunnicliffe, 2008). The pilot interviews study consists of pre-post interviews with fifteen 3rd and 4th grade primary school children during a three-day summer vacation offer in 2022. The adapted and translated questions based on Cohen & Horm-Wingerd (1993) and Prokop & Tunnicliffe (2008) addressed the children's opinions, observations on their environment (plants, trees, flying animals), and what they know and think about bats. The interviews where recorded, transcribed and analysed with qualitative content analysis (Kuckartz & Rädiker, 2023).
Qualitative data is also collected via work-in-progress-reports of teacher students and analysed with qualitative content analysis. Digital learning offers were developed in scratch (web-based programming) and CoSpaces EDU (browser-based tool to design virtual and augmented reality spaces). Teacher students reflected what potentials and problems may arise with pupils and to what extent the project has an educational added value.
For collecting quantitative data an online questionnaire based on Vincenot et al. (2015) focusing on bats and their living environment in Germany and Europe was used in 2023.

Findings:
Pupils are interested in "superpowers" of bats and see them as "heroes in the night sky". If asked, what superpower they would like to have themselves, they often mention the ability to fly (75 %), to sleep very long and overhead (50 %), and to eat a lot (65 %). They are fascinated about the ability to "see with ears" and to be able to orient themselves in darkness.
Teacher students (85 % female) find the gamification elements interesting, but are insecure about their own abilities to use them in class – they often argument with the technical and computer science aspects of gamification elements and barriers of knowledge. They are convinced, that the offers "encourage motivation and interest of the students". Most of the teacher students reflected that with their own developed offers they gained knowledge about bats, their importance and how to use gamification elements and digital media for their teaching.

Conclusions:
The learning offers show potential to increase species protection awareness in pupils and teacher students. Teacher students need support in order to use digital media and gamification for their later teaching.

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Packing ecology principles and sustainability challenges into an educational game. The FRACTAL game experience.

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Introduction

Sustainability is a complex issue and often intertwined with social and economic aspects and requires not only a strong background in in ecology, biology, chemistry, and physics, but also high-level skills in systems thinking, future scenario building approach, hands-on approach, and negotiation [1], [2]. Students show difficulties in internalising knowledge unless a responsive, dynamic and process learning is enabled, simply because for most of them, it is too abstract or detached from their day-to-day experience [3], [4]. To provide an adequate education to the students, a shift in didactic approaches adopted in Environmental and Sustainability Education (ESE) is mandatory. A more student-centred and active education can help students not just in the acquisition of scientific knowledge but also in practising some key competencies such as systems and critical thinking or future scenario-building ability [2], [5]. Game-based learning (GBL) is an approach in which games are adopted to facilitate the exercise of what students learn in a more realistic and engaging context [4]. Studies have demonstrated that educational games (EG) provide immersion, motivation, fun and engagement, facilitating the retention of contents studied [4], [5]. Studies also found that EG can teach 21st-century skills, the key skills to manage sustainability issues [2], [6]. Games in ESE can generate awareness about environmental and social threats, illustrate how complex systems and ecosystems are structured and work and, can involve the learners in complex situations where their decisions have a noticeable impact [6], [7]. Specifically, serious games are games designed to reach some specific educational outcomes and they are increasingly adopted in ESE both in formal education contexts and in non-non-formal education [6]. To be effective a game about ESE should be designed with an interdisciplinary approach based on pedagogy, biology, and design [8].

Research objectives

In this paper we discuss the structure of the FRACTAL board game, developed within the FRACTAL (FosteRing green infrAstruCTure in the ALps)project. The aim of the FRACTAL game is to increase the awareness of young people on Green Infrastructures (GIs) and their role in supporting ecosystem services and ecosystem conservation in the Alps. Objectives of this research are: 1) discuss how specific ecology concepts, critical and systems thinking, future scenario building, negotiation and cooperation skills can be embedded into the board game and 2) explore the game playability and its efficacy in boosting students' awareness about GIs and ecosystem services.

Design and methodology - This research employs the educational design science research [9] theoretical approach to the educational problem targeted and applies two different methods in the practical part of the research: the educational game design model (EGDM) [10] as design framework and a specifically modified version of the MEEGA+ model [11] for the game evaluation. The EGDM has been adopted to design the scientific contents and educational output and how to fit them with mechanics, dynamics, and aesthetics. In the game development phase, a group of four with diverse backgrounds (a researcher in engineering expert in game design, a science teacher expert in didactics of Biology and GBL, a researcher in science education and, a designer expert in games and naturalistic illustrations) cooperated. After the game prototype production through an iterative process, e the definitive version of FRACTAL game was delivered and the GBL format was defined. Two high-school classes (16 –18 years old) were involved in the first FRACTAL playtest.

Findings and Conclusion

The FRACTAL game was evaluated as effective in stimulating players to discuss and deepen some key ecology concepts. Additionally, it was confirmed that GBL is a satisfactory solution in supporting students to put in practice the ecology concepts learned. Students appreciated the game playability and engagement. However, to confirm the game effectiveness in introducing and deepening some key ecology concepts, other tests in a long-term perspective are required. Additionally, this research highlights the need for a multidisciplinary approach in designing didactic tools to favour a deeper understanding of ecology concepts.

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SYMPOSIUM

When Socioscientific Inquiry-Based Learning meets Open Schooling: The COSMOS approach to Science Education

Towards a multidimensional model of school openness through science education

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Theoretical background

In the past few years, the OECD (2006, 2020) and European Commission (EC, 2015) have been instrumental in rearticulating ‘open schooling’, specifically targeting the breaking down of school walls and opening schools to the community. The EC defined open schooling as follows: “Institutions that promote partnerships with families and the local community with a view to engaging them in the teaching and learning processes but also to promote education as part of local community development” (EC, 2015, p. 69). This reconceptualization of ‘open schooling’ incorporates previously associated attributes such as inclusivity and pedagogical innovation (e.g., Haughey et al, 2008) yet is specifically focused on the idea that ‘openness’ concerns rethinking and extending the boundaries of who is engaged in learning, who benefits from the learning process, where does the learning take place, and who is involved in determining what and how is being learned.
The above understanding of openness assumes that schools play an active role in promoting community well-being and the cultivation of democratic citizenship and social responsibility. The EC report further elaborates open schooling, in the context of science education, by calling for partnerships between teachers, students, researchers, innovators, professionals in enterprise and other stakeholders in science/biology education and related fields, to “work on real-life challenges and innovations, including associated ethical and social and economic issues” (p. 69). Thus, the EC highlights the connection between open schooling and Responsible Research and Innovation (RRI), and the creation of a community of responsible inquiry in the context of science/biology education.
Additional developments have been made within several EC-funded projects and networks, all focusing on how to apply open schooling in the context of science education. The characteristics of school openness highlighted by Sotoriou et al (2017) not only underscore the creation of partnerships, collaboration and interconnectedness among schools and various stakeholders, but also responsible research and educational excellence. Findings from research conducted (Sotiriou et al, 2021) indicate the effectiveness of implementing an open schooling approach for enhancing students’ scientific knowledge and skills.
Further developments in the understanding of open schooling have been made in more recent EC-funded projects and networks, yet their central focus is on the development of tool kits, materials and educational designs for implementing open schooling in practice. While important developments have been made, we argue that much more theoretical work is needed in order to gain a better and more systematic understanding of what school openness is and what is entailed in implementing open schooling in science/biology education.

Key objectives

The main objective of this presentation is to present developments made as part of the COSMOS project towards the articulation of a multidimensional model of school openness, which we argue further expands and deepens the understanding of what school openness is and how it could be realized in practice.

Research design and methodology

The multidimensional model (Figure 1) was constructed by rigorous literary analysis of the open schooling literature, primarily policy reports (OECD, EC) and various EC- funded projects dedicated to the investigation and implementation of school openness (Sotiriou et al, 2017, Sotiriou et al, 2021). The present model expands its methodological resources by connecting to two key discourses: the school as community literature (e.g., Furman, 2002; Sergiovanni, 1994) and Schwartz’s (1992) circular continuum model of values. The openness model has been further developed through focus group interviews conducted with school teams participating in the COSMOS project. The data collected from these interviews contributed to the concretization of openness levels in diverse school contexts.

Findings

On the basis of the literary analysis and focus group interview data, we present a model of school openness that is composed of eight interrelated yet distinct dimensions. The eight dimensions of openness are organized and depicted on a circular visualization, which indicates different types of openness (organizational, pedagogical, community- related) and the relations among them. Each dimension constitutes a continuum ranging from inward to outward. For assessment purposes, we have

added an additional mid- level marker, 'in-between', that allows gaining more precise characterizations of openness, both conceptually and practically.
Through focus group discussions with school teams implementing COSMOS in their science education, we have collected data that allows us to (1) validate the theoretical model of school openness, (2) describe what the different dimensions of openness can look like in actual educational practice, and (3) map which factors are identified as facilitators and barriers to developing schools towards more openness, both in general and within their science education.

Conclusions

The model presented here attempts to make contributions to the understanding of school openness as a facilitator for engaging in meaningful science/biology education: it seeks to (1) increase conceptual clarity, including a distinction between different types and areas of openness as well as addressing the relations among the different types of openness; (2) expand the scope of openness by incorporating additional dimensions of openness; (3) offer an alternative (circular) mode of organizing the characteristics of openness including visualization to enhance clarity and coherency. The model has various practical applications, including a conceptual basis for engaging in teacher professional development and teacher capacity-building, an assessment tool to investigate open schooling attributes in different school contexts and a basis for developing research tools for investigating educational interventions.

* *This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101005982'*

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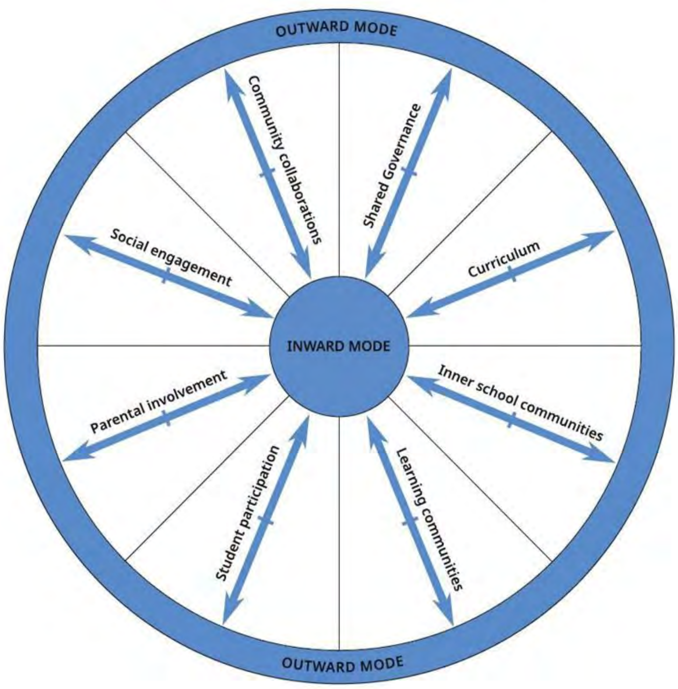

Figure 1: school openness model

Adapting TPD in 'cosmos' to diverse educational settings – Insights from first implementation

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Rationale and theoretical background

The HORIZON EU 'COSMOS' project targets opening schools to their communities and fostering meaningful science education by connecting science to the learners' real world (Sotirou et al., 2021). COSMOS employs socio-scientific inquiry-based learning (SSIBL) as the pedagogy for developing, in communities-of-practice (CoP), learning units for science classes around socio-scientific issues that are relevant to the community. Through this, COSMOS intends to foster scientific literacy and responsible citizenship.

Capacity building of school teams is crucial to this process. This is the role of teacher professional development (TPD) in COSMOS, in which capacity building targets three professional competencies required of the teachers: their professional teacher identity regarding learning in/as a community and open schooling; skills in implementing SSIBL; capacity as reflective practitioners. Accordingly, COSMOS TPD connects three discourses: the extensively theorized notion of teacher professional identity (Cordingly et al., 2019; Suarez & McGrath, 2022), SSIBL pedagogy for learning biology and science subjects embedded within socio-scientific issues (Ariza et al., 2021), and teachers as reflective practitioners (Shah, 2022; Smith et al., 2016). Promoting open schooling, in which schools do not operate as isolated entities but in interaction with the community they are rooted in, is an example of the changing educational context in which teachers operate. This requires supporting them in cultivating the professional identity enabling them to effectively function in these new circumstances. While inquiry-based learning is prevalent in teaching biology and science subjects, SSIBL presents a societally responsible approach integrating inquiry- based learning around SSIs and citizenship education (Levinson et al., 2017). Science teachers' capacity to apply this pedagogy deviates from their experience in mainstream inquiry-based teaching. Key to being an effective teacher is the ability to critically reflect- to examine and learn from experience/educational situation towards using this knowledge to reframe one's thinking and improve one's teaching. This is especially crucial when considering the role of education as means for change and of teachers as change-agents (Smith et al., 2016), as is the case of COSMOS.

Objective

Considering the multinational and diverse school contexts in which COSMOS is being developed, a challenge is adapting TPD to different educational circumstances while maintaining the integrity of the COSMOS approach. This challenge is significant in view of "the embedded or situated nature of teacher professional learning and development: within the school environment and its culture, and in relation to how educational systems and policies effect their work lives" (Alvos, 2011, p. 13). This presentation offers initial insights regarding this challenge after one year of implementing COSMOS.

Methodology

A rigorous iterative design process led to the TPD framework, which is structured around three conceptual stages corresponding with the conceptual foundations of COSMOS (Figure 1) and engages teachers in three possible scopes of participation (Figure 2). Aligning with the COSMOS approach of cultivating CoP, TPD is directed at the country level (*COSMOS-schools-community-arena*) with teachers from all the participating schools, the *school-level* in which the professional learning community involves the participating school team. Individual teachers are also provided guidance and support.

After completing the first year of implementation in 15 schools, project leaders from each of the six participating countries provided a detailed report regarding various aspects of TPD implementation. Findings are presented regarding major adaptations necessitated in each national or school context.

Findings

In all implementations, TPD actions addressed the three conceptual components (learning in/as a community, SSIBL-CoP, reflection) and in 5/6 countries, TPD structure and sequence were largely followed; the major deviation being in the number of TPD sessions conducted in each stage, dependent on time resources of the participating teams. Owing to the diversity of implementation circumstances, it is not possible to extract a common thread of adaptations, but rather to identify different types of factors that determined the necessary adaptations: (a) *openness attributes* of the participating schools identified with the multidimensional school openness tool (see Sarid); (b) *content-related*– teachers' familiarity with concepts such as SSI, CoP, inquiry-based learning; (c) *aligning TPD with other COSMOS actions*, mainly coordinating TPD activities with the implementation work-plans of each school and assessment actions; (d) *administrative/logistic factors* such as time constraints of the teachers (in-school administration), higher-level (out-of-school) administration constraints; (e) *participant scope* - with whom TPD activities were conducted. In most countries, TPD activities were conducted at the 'school level'. Exceptional are Portugal and Israel. In Portugal, TPD was conducted at the 'COSMOS-school-community- level', reflecting how COSMOS is implemented in this country, in school 'clusters'. In Israel, activities included 'school-level' and 'COSMOS-school-community-level', resultant of governmental support (Ministry-of-Education).

Discussion

Adapting TPD to diverse educational circumstances while maintaining the integrity of COSMOS is essential towards delivering a theoretically grounded TPD-framework for realizing SSIBL pedagogy within a CoP that is applicable in diverse educational settings. Each country in which TPD was implemented comprises different macro conditions (e.g., how the education system operates, the teachers' working conditions, nature of policy environment and reform) and within this, each school comprises a different microcosm (e.g., school culture e.g., administrative and organizational structures) (Avalos, 2011). Findings emerging from COSMOS's first implementation suggests several types of factors to be considered when conducting COSMOS TPD that correspond with macro and micro conditions identified in the literature in relation to TPD and toward refining COSMOS TPD.

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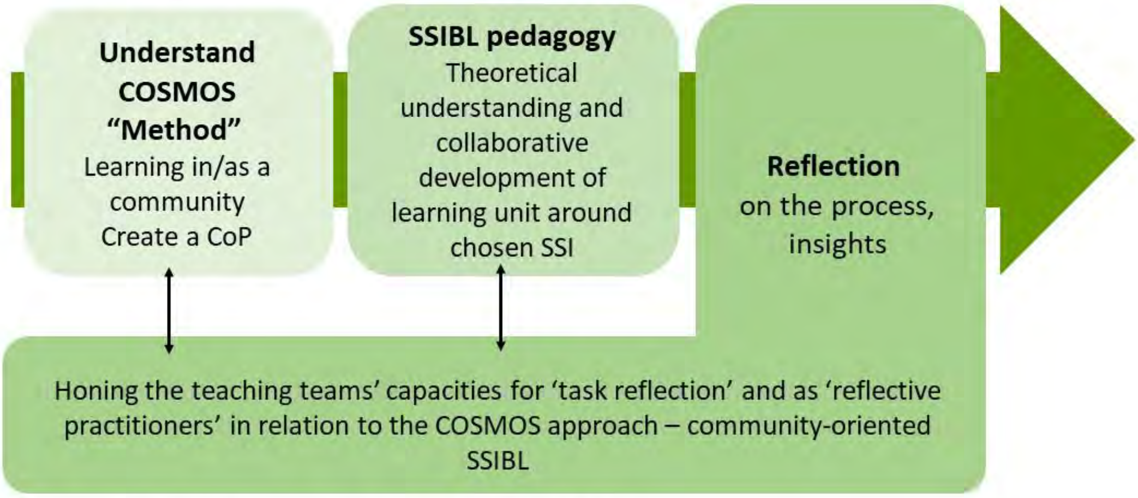

Figure 1. Three conceptual stages of TPD in COSMOS

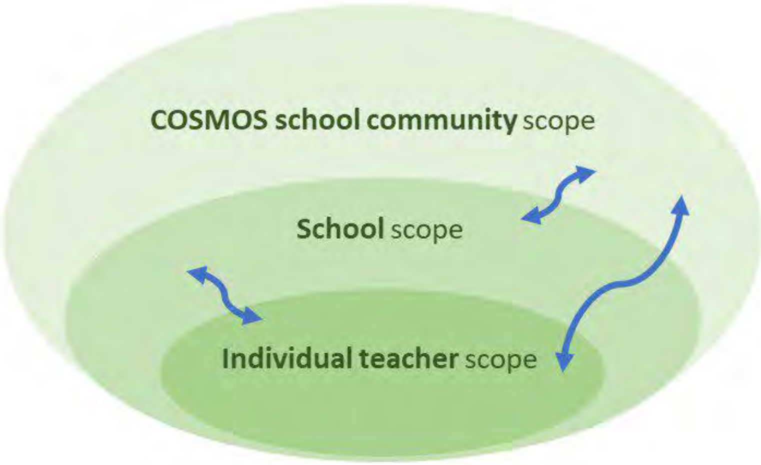

Figure 2. Three scopes (arenas) of TPD participants

"I feel that what i do matters". The impact of ssbil-cop implementations on student outcomes

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Theoretical background and rationale

In the ever-increasing VUCA (volatile, uncertain, complex & ambiguous, Bennet & Lemoine, 2014) reality of societies across Europe and beyond, there is a strong need for scientifically literate citizens who are willing and able to contribute to a more sustainable future. Education is seen by many as one of the key factors that can and should contribute to this goal. SDG4 (Quality Education) explicitly addresses the need to equip all learners with competences that allow them to be(become) active and responsible citizens towards of the wicked sustainability issues we collectively face. One approach that has, in this respect, attracted attention in recent years is that of open schooling. Sarid et al. (2023) conceptualize school openness in relation to three key features of schools: organization, pedagogy and community-relations. In an earlier contribution in this symposium, the openness model is presented in detail.

The model was developed in the context of the Horizon Europe project COSMOS, which aims to support schools in their development towards school openness and connect science education to real life and stakeholders beyond school walls. The key lever driving these processes of professional and organizational development, is the implementation of socio-scientific inquiry- based learning (SSIBL, Knippels & Van Harskamp, 2018) through a communities-of-practice approach (CoP, Wenger et al., 2002). Both SSIBL and CoP will get attention in earlier presentations in the symposium. The current proposal contributes insight into the impact of implementations of SSIBL-CoP in biology and science education on students' learning outcomes. It has been described that applying open schooling can promote students' attitudes towards science, science career aspirations and active citizenship (Sotiriou & Cherouvis, 2017), especially toward addressing social-environmental issues. The COSMOS project provides rich opportunities to study such effects in diverse schools across Europe.

Key objectives

We hypothesize that SSIBL's explicit focus on scientific, social and personal inquiry and its orientation towards learners' deliberate action taking, combined with the real-world and collaborative nature of the CoP approach, are a potent mixture to drive student learning. Our central research question is, therefore:

> *What is the impact of SSBIL-CoP implementation on students' attitudes towards science and action competence?*

Research design and methodology

Research context, data collection. COSMOS is a European Horizon 2020 project, aimed at supporting schools to develop their openness. Teacher teams from primary and secondary schools from the Netherlands, Belgium, Sweden, Portugal, the UK and Israel are supported to implement SSIBL-CoP into their science education, in two year-long rounds of professional development and implementation in practice. The current proposal works with the student data collected from the first implementation round. In total, 480 students from 12 schools participated in online pre-post surveys. Data was collected before and within two weeks after the teacher teams indicated that they had completed their SSIBL-CoP implementation. Student age averaged at 12,5 (±2,3), and most SSIs centered around biology and/or sustainability. More information on professional development, as well as an exemplary case study description of one implementation in one school are provided earlier in this symposium.

Variables. The students' learning outcomes were assessed by using two commonly applied validated quantitative measurement instruments: a modified version of the Pupils Attitudes Towards Technology (Ardies et al., 2014), and the Self-Perceived Action Competence Scale (Olsson et al., 2020). While the first taps into students' science career aspirations, interest in science, tediousness of science, gendered science views, relevance and perceived difficulty of science, the latter taps into students' self-perceptions of how much they know about contributing to sustainability, their self-effectiveness and willing to act towards sustainability. Each of these concepts is measured through a minimum of three items on a 5-point likert-type scale (1=strongly disagree, 5=strongly agree). After each items batch, students were invited to add anything they felt relevant in open questions in the survey.

Data analyses. We used personal identifiers of individual students within schools to track the development of students across time. Given the nested data structure (repeated measures within nonrandom distribution of students across schools), multilevel analyses are appropriate. However, given the limited number of schools in this first implementation round, the current data analyses apply repeated measures t-tests to study differences pre-post implementation. By the time of the presentation itself, the second implementation round will have passed, and more advanced data analyses will be possible.

Findings

The results show differences between pre- and post-implementation for some of the subscales of the two main learning outcomes that we have in scope (see figure 1). Overall, the current intermediate results after one round of professional development and implementation of SSIBL- CoP in the schools' science education, show small to moderate effects (all Cohen's d < 0.5) in terms of the students' interest in science and perceived relevance of science. No overall effects were observed for the students' science career aspirations, gendered views of science, perceived tediousness and difficulty of science. In terms of action competence, the intermediate results point out small to moderate effects (again, Cohen's d < 0.5) in terms of confidence in their own influence to contribute to a more sustainable world as well as their willingness to act accordingly. No overall effect was observed for the student's self-perceived knowledge of action possibilities.

Conclusions

The results of these initial analyses highlight some interesting effects. Across the 12 schools that participated in the first implementation round, students report increased interest in science as well as attributing increased relevance to science. Furthermore, these initial results show that implementing SSIBL-CoP, in which schools specifically work on real world socio-scientific issues, apply scientific, social and personal inquiry, and collaborate with stakeholders in that SSI, positively impact students' confidence in in their own influence and their willingness to act. It is important to stress that these are initial results, and they are aggregated across all the schools in the sample. Differences among schools will exist, e.g. pertaining to the educational level (primary and secondary), the type of education offered at the schools (academic or vocational), and the implementation fidelity of the SSIBL-CoP approach. After the second implementation round, we will be able to address such differences and study the impact of open schooling on student learning in more detail.

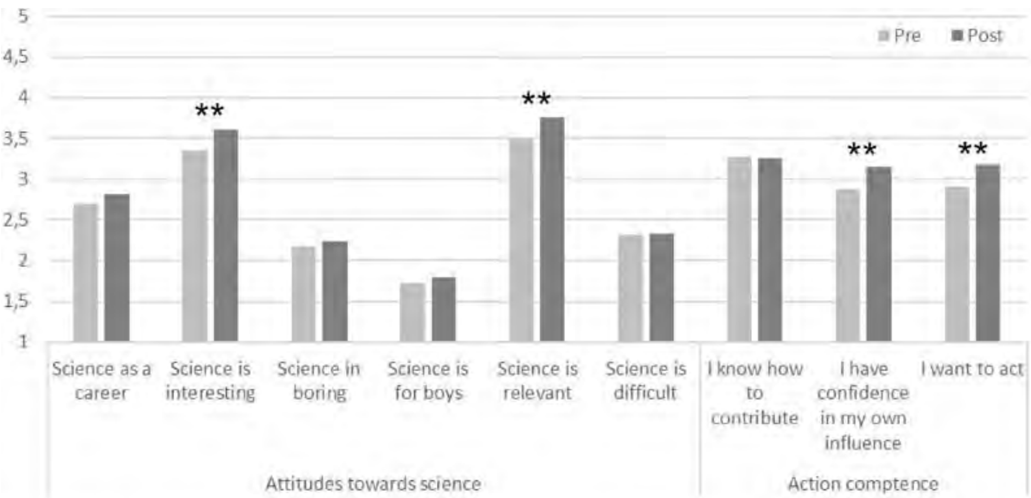

Figure 1. Summary of pre-post comparison of students' responses to the survey on attitudes towards science and action competence, before and after the first implementation round. ** marks significant differences at p < 0.01.

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Socio-scientific inquiry-based learning and community engagement for open schooling

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Rationale

Today's society faces various challenges (e.g., climate crisis). Being able to navigate these socio-scientific issues (SSI) and to contribute to resolving them calls for scientifically literate citizens who are critical consumers of scientific knowledge and agents-of-change, able to make decisions and take *responsible* action. SSIBL (Socio-Scientific Inquiry-Based Learning) is a pedagogy that aims to foster responsible citizenship by connecting SSI-driven inquiry and taking responsible action (Levinson, 2018). In this open schooling approach, underpinned by SSIBL, we explore opportunities to include stakeholders (e.g., families, scientists, companies, science centres) related to the SSI in focus, and as such build a Community of Practice (CoP) that collectively works towards addressing localised SSIs through science education. By combining SSIBL and CoP in primary and secondary biology and science education we aim to empower teachers with conceptions, tools and teaching activities that can assist them in supporting students' science learning as well as learning to contribute responsibility within their communities.

SSIBL and Communities of Practice

SSIBL combines citizenship education, SSI-based education and inquiry-based learning, in an attempt to promote science *in*, *with* and *for* society underpinned by the responsible research and innovation (RRI) principles of social desirability, ethical acceptability, and sustainability (Levison, 2018). SSIBL consists of three interconnected stages: raising authentic questions (ASK), through emergent SSIs that require a solution; integrating social, personal and scientific inquiry to explore these questions (FIND OUT); and, collectively taking responsible action (ACT) (Knippels & van Harskamp, 2018). The focus of SSIBL on identifying solutions through personally-relevant inquiries allows students, teachers and schools to work collectively to address issues relevant to them and their communities. In doing so, the use of SSIBL for biology and science education, becomes a pedagogical means of opening schools to their communities. Using SSIBL to learn and mitigate against local, relevant issues (e.g., biodiversity loss) and contributing to the community can demonstrate the relevance of science to all participating members, creating common ground for collaboration and shared learning, and thus supporting the development of CoPs within these social settings. A CoP is characterised by *joint enterprise,* which is agreed and negotiated through collective participation and *mutual engagement* using a *shared repertoire* of resources co-created over time (e.g., language, values), created when individuals work together within a certain set of social norms and routines and thus develop a shared way of seeing, doing and being, a shared practice (Wenger, 1999).

Key objective

To what extent can SSIBL and CoP dimensions be integrated to promote open schooling practices through biology education?

Research design and methodology

This study is part of the COSMOS project, which builds on previous work on SSIBL (Ariza et al., 2021) using it as a tool for opening up schools to their communities and beyond. During the first round of this design-based research study, we worked in 7 primary and 8 secondary schools across 6 countries (Netherlands, Sweden, UK, Portugal, Belgium, Israel) with teacher teams (40 primary/40 secondary teachers in total) to co-design and implement 'Open SSIBL'. Data collected included the co-designed materials, lesson observations, reflective logs, and notes from meetings between teachers and researchers. Our analysis framework is pre- determined based on the three SSIBL stages and the three CoP dimensions.

Findings

Ten of the 17 'Open SSIBL' implementations focused on biology-related SSIs (Table 1). Due to space limitations, we expand here on the first UK implementation (Year 2, 6–7-year-old students), focusing on biodiversity loss, to discuss how SSIBL and CoP dimensions were embedded in the materials co-designed and implemented. We will present our full analysis in the presentation and conference proceedings.

Table 1. Biology SSIs covered in each national context and SSI questions

Country – Education Level	Topic	SSI question (unit duration)
UK – primary (3 implementations in same school)	Biodiversity loss	Should we keep the school pond? (10h approx. with Year 2) (12.5h approx. with Year 3) (12happrox. with Year 5)
Israel – primary	Animal welfare	How can we improve the conditions of the animals in our school farm? (14h approx.)
Israel – primary	Bee husbandry	Why are bees disappearing and what can we do to address this? (17h approx.)
Israel – primary	Healthy lifestyles	How can we promote adopting a healthy lifestyle in our community? (7h approx.)
Portugal – primary & secondary collaboration	Biodiversity loss	Biodiversity loss: what are the causes, the consequences and the possible actions to avoid this problem? (20h approx.)
Sweden – secondary	Genetically modified crops	Are GMO something good or bad? (16h approx.)
Israel – secondary	Nature conservation	What is the importance of maintaining the Gazelle Valley as an urban nature reserve? (15h approx.)
Netherlands- secondary	Air Pollution & healthy living	Should we ban all fossil fuel scooters and cars from the city? (3.5h approx.)

The SSI question guiding the 5-lesson unit, co-designed with two Year 2 UK teachers, indicates explicitly the community level (school), and ACT ('should we'), creating from the start a need to take action. The *joint enterprise* dimension of CoP was introduced in Lesson 1 by presenting children with a letter from the Headteacher, who was asking for their help in deciding whether to keep the pond. This created an issue that children and school staff were addressing collectively. Children then worked on mapping the controversy in whole class with their teachers, and identifying further stakeholders they could assist them in answering their question (e.g. parents, consecration experts, university researchers). They decided what questions to ask these stakeholders who attended Lesson 2 where *mutual engagement* and a *shared repertoire* were developed between the formulated CoP to exchange knowledge, and views about the issue as part of FIND OUT. This CoP dimension was also evident during Lesson 3 where children visited a local outdoor learning centre to learn more about ponds and how to improve their own (FIND OUT).

Children also investigated microhabitats and the biodiversity that exists around their school pond in Lesson 4 and in making their final decisions about keeping the pond, they communicated their findings and suggestions for keeping the school pond and improving it to enhance biodiversity as *joint enterprise* with school governors (ACT).

Discussion and Conclusions

At the design stage, the SSIBL units addressed all SSIBL stages, although the ACT stage was not always implemented due to practical issues (e.g., workload) or conceptual issues (e.g. students asked to design a poster but without presenting this as an action to address the SSI). Where successful implementation of all SSIBL stages was achieved (all primary schools), this also showed key dimensions of CoP being addressed or developed, as explained in the UK case. The time required to develop some of these dimensions (e.g., shared repertoire) posed a challenge for teachers, especially in secondary schools, and additional support was needed to achieve this. Therefore, in the next round, we aim to support teachers' instructional practices on the ACT dimension of SSIBL as well as how they can draw on a wider range of their school's repertoire of resources for supporting children's biology and science learning in, for and with their communities.

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Working with genetically modified organisms as SSI within the cosmos project - A case study from Sweden

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Theoretical background

In 2015, The European Commission published "Science Education for Responsible Citizenship," proposing the idea of Open Schooling (EC, 2015). In open schooling environments, external perspectives are encouraged to challenge and reshape traditional education, benefiting students and the community (Sotiriou, Sotiriou & Bogner, 2021). These dynamic environments can play a crucial role when student projects address real-world needs and enhance local expertise. In a previous project socioscientific inquiry-based learning (SSIBL) was developed to support students to become 'agents-of-change' within their communities (Christodoulou & Grace, 2019; Knippels & van Harskamp, 2018). In addition to using SSIBL, a model has been developed within the European project COSMOS, integrating SSIBL with the approach of Communities of Practices (CoP) (Wenger, 1998) to enhance school openness, students' interest in science, and scientifically literate citizens, who are critical agents-of-change, able to make decisions and take responsible action.

Key-objectives

In this study, we present an example of implementing the COSMOS model, focusing on the collaborative efforts between teachers and students in a Swedish secondary school, researchers affiliated with a nearby university and staff from a museum of contemporary art. We present how the socioscientific issue of Genetic Modified Organisms (GMO) was chosen and elaborate on the integration of SSIBL-CoP. Hence, the key objectives of this study are to illustrate and evaluate the outcomes of using GMO as a theme, working with a SSIBL-CoP approach in a Swedish secondary school. The following research question was posed: *How does the choice of GMO as SSI influence the level of school openness and engagement of students and teachers in SSIBL-CoP activities?*

Research design and methodology

The participants in this study came from a school situated in the middle of Sweden. The school and the university had previously worked together for many years, with teachers interested in improving their biology and science teaching. Students, 14-15 years old (altogether about 100 students), four science teachers, an art teacher and the principal at the school participated in the project. Eight students participated in focus group interviews conducted before and after implementation. In addition, interviews were held with two of the science teachers before and after activities.

The implementation started with the pre-focus-group interviews to identify current status of students' interest in science and how the students experienced the science lessons and the science teachers' view of the current level of school openness. The pre-interviews were followed by co-design of learning units. These were made by the two science teachers leading the project at the school, the museum pedagogue and a researcher from a university.

GMO was chosen as the theme based on what kind of SSI the museum could offer and what the science teachers found to be related to the curriculum. Some of the learning units had a special design used at the museum with focus on an art-based inquiry-based strategy (Raaijmakers, McEwen, Walan & Christenson, 2021). In addition, learning units were designed by the science teachers with support from the researcher from the university. These units included teaching resources that explain the concept of GMO and the pros and cons of its use. At the end of the project the students had debates and presented an exhibition of their own artworks showing different aspects of GMO. The exhibition was shown in the school cafeteria, open to all students in the school. After implementation, interviews were held with the same students and teachers as before. All interviews were audio-recorded and transcribed. The transcripts were analysed thematically using the model from Braun & Clarke (2006). The analysis was made by the first author and later checked by the other authors to discuss and agree on the coding.

Findings

Coding of data resulted in three main themes: *Motivated student and teachers*, *SSIBL and CoP as separate experiences,* and *Integration of SSIBL-CoP.* Short presentations of the themes are presented as follows.

Motivated students and teachers

The students were highly engaged during the project and expressed that they learned more about GMOs through this experience than they would have in a traditional classroom setting. Student engagement was confirmed by the teachers who also expressed a desire for more activities outside of school. They noted that such experiences can be more motivating for students.

SSIBL and CoP as separate experiences

The teachers argued that working with SSIBL was nothing new and they use this teaching approach when it is suitable with the content to be taught. Using a CoP approach was mentioned as something not previously used. However, teachers emphasised that this was something they wanted to elaborate.

Integration of SSIBL-CoP

The collaboration between the school and the university was facilitated by an existing network. The principal of the school was supportive, and the school also had a previous collaboration with the museum. However, finding additional stakeholders related to GMO as chosen SSI turned out to be difficult. This was mainly related to the context where the school is situated, with no stakeholders directly involved in GMO.

Conclusions

The participants were positive to adopt the COSMOS approach and the project has encouraged the school to seek more societal collaborations, further enhancing its openness. The school openness model in the COSMOS project includes many aspects, but for this school, collaboration with society was the aspect they were most interested in developing. Even though there were challenges in terms of limitations in finding CoP members due to the choice of SSI, the main outcome was considered as positive. The teachers are eager to use another SSI to develop more collaborations with the surrounding society.

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Informal Education

Promoting Understanding of Evolution Theory through a Science Comic Intervention in the ECOSCOMICS Project

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Theoretical background or rationale

The presented contribution examines the potential of *science comics* (SC) created in order to promote the understanding of biological concepts. SC are used to communicate science content (Jian, 2022) and pursue a science didactic learning objective (de Hosson et al., 2018). Even though using narrative tools in science education is promising (Avraamidou & Osborne, 2009), the potential of SC has rarely been studied (de Hosson et al., 2018). The Erasmus+ project ECOSCOMICS (2021-1-FR01- KA220-SCH-000030110) unites science educators, scientists and professional artists in an effort to develop web-based SC on seven scientific topics. Each episode addresses the core concepts of the topic as well as prominent alternative conceptions. This contribution focuses on the evolution episode. Abstract and counterintuitive concepts such as natural selection are particularly challenging for science teachers, as conceptual change processes depend on the learners' prior conceptions (Vosniadou et al., 2008). Some authors underline the potential of SC that address these alternative conceptions or contrasting conflicting scientific perspectives (Özdemir & Eryılmaz, 2019). Furthermore, SC can increase learners' engagement and motivation (Maron et al., 2019). However, we still lack empirical evidence on the effectiveness of SC, particularly in secondary education.

Key objectives

Our main objective is to test whether the evolution episode can help students to understand natural selection and the associated concepts, and which teaching-and-learning arrangements (TLA) are productive for embedding the SC into teaching units on evolution.

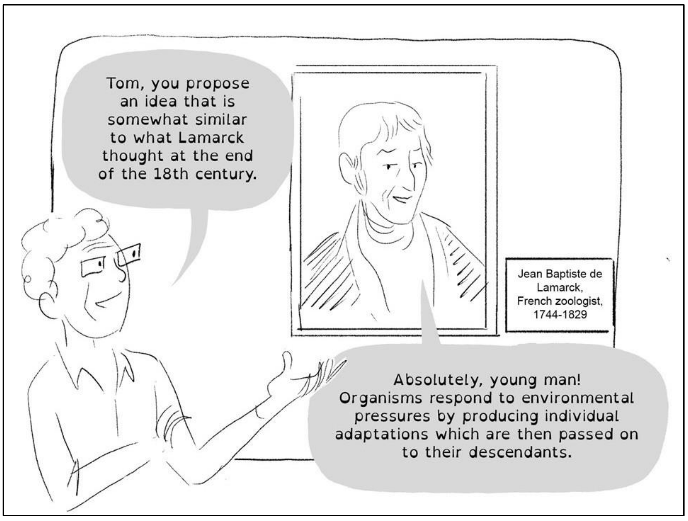

***fig. 1*:** Extract of the ECOSCOMICS SC beta storyboard on evolution (all rights reserved), 2023.

Research design and methodology

The beta storyboard of the SC episode on Evolution (fig. 1) was tested in 2023 in classroom contexts of the ECOSCOMICS partners in Germany, Portugal and Poland. Our overall design did not attempt to make the results comparable by eliminating "noise" between different contexts. Instead, every partner used different TLA and research designs (fig. 2). In this way, despite the small sample sizes, we were able to explore a broad range of aspects around the learning process with SC, and to test different ideas for TLAs integrating the SC.

In both the German and the Polish study, KAEVO 2.0 questionnaire (Kuschmierz et al., 2020) was used to measure the student's understanding of biological concepts, and thereby the effectiveness of the intervention. While in the Polish team students read and discussed the SC as part of their regular

evolution unit, the German study used the SC afterwards with different delays in the respective sample groups. In the German intervention, a worksheet accompanied the students' reception of the SC in order to enhance the conceptual change processes. Individual student interviews focused on the narrative, visual and factual dimension of the SC, and their interplay.
The Portuguese used two different TLAs: (1) students read the SC and then answered a specific worksheet, examining the students' interpretation of the plot while considering biological concepts. Worksheets were qualitatively analyzed. In arrangement (2), students autonomously explored one of the three chapters of the SC in groups and presented their work to the classmates. Afterwards, interviews were conducted in order to collect students' and teachers' experiences with the new medium.

country	students' age (school level)	time relative to regular evolution unit	research design and TLA characteristics	method of data collection (sample size)
Germany	16 years old (secondary school), 15 years old (high school)	6 months later 1 week later	mixed method, pre-post design, different delays, worksheet-guided TLA	**KAEVO 2.0 questionnaire** (Kuschmierz et al., 2020) (n=23; n=35); **students' interviews** (n=4; n=3)
Portugal	16-17 years old (secondary school)	1 week later	3 classes, two different TLAs: (1) worksheet-guided and (2) autonomous exploration	**worksheets** (n=18; n=19; n=7) **teacher interviews** (n=3) **student interviews** (n=7)
Poland	15 years old (highschool)	during evolution unit	pre-post design	**KAEVO 2.0 questionnaire** (Kuschmierz et al., 2020) (n=10)

fig 2: Table of data collection designs in the three involved European countries

Findings
Germany: The first sample group (6 months delay) showed a significant increase for the natural selection items of the KAEVO 2.0 (Wilcoxon: $p=.01$, $r=0.47$). In contrast, the second group (1 week delay) showed no such effect, suggesting that the SC was more efficient with students with low prior knowledge. Interview results highlight that the students appreciated the interplay of pictures and words and the reduced number of technical terms compared to textbooks.
Portugal: The analysis revealed that the SC allowed the students to discuss and explain a wide range of issues related to evolution, and to frame the concepts of Lamarckism, Darwinism and NeoDarwinism in a much broader context than usual. The worksheet analysis showed that some common misconceptions were well addressed through the episode. According to teachers' perspective, the evolution episode is a very effective didactic resource, since it seems to arise students' interest and motivation. The students shared this opinion, characterizing the SC as "a different and appealing way of studying evolution".

Conclusions

The studied SC episode on evolution has the potential to promote understanding of the evolution theory and to reduce known alternative conceptions in a motivating format. Addressing specific misconceptions appears to be one of the medium's strengths. Our results suggest that this SC is most efficient in an autonomous teaching arrangement (Portugal), and also for students with less prior knowledge (Germany).

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How do high school students learn with and about coral reef models in natural history museums?

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Theoretical background

Natural history museums (NHM) are authentic places for doing science that expose visitors to a variety of systems and models. A scientific model is an abstract, simplified, representation, which makes its object's central features explicit, visible and can be used to generate explanations and predictions. Scientific modelling includes both the act of constructing, using, evaluating, and revising models, and the relevant metaknowledge, like understanding their nature and purpose (Schwarz et al., 2009).
Models are often used to describe systems, make them comprehensible or make predictions about their behaviour. To understand the complexity of biological systems, students must develop system thinking, which is expressed by identifying relationships between system components and/or systems, considering multiple levels and causal relationships in order to explain a target phenomenon. Research has suggested that the external representation of mental models through concept maps contributes to both teaching and assessing students' understanding of complex systems. This study followed a group of students during an intervention program consisting of four modelling-based NHM visits on the topic of coral reefs, analysing the concept maps and modelling artefacts that they created after each experience to trace developments in their understanding of scientific modelling and the coral reef ecosystem.

Key objectives

To examine the development of students' understanding about models, following exposure to different model types during the NHM intervention.

Research design and methodology

Our study followed 24 German ninth-graders who participated in an extracurricular activity. After an introduction to the topic of coral reefs and group discussion about models and modelling, they visited models of coral reefs in different learning environments (NHM reef diorama, VR experience of a dive in a reef, live coral reefs in the aquarium). After each visit, students talked about the possibilities and limitations of models in subsequent analysis discussions. In final reflective interviews, the students were asked about their understanding of models.
Our research design is based on the work by Schwarz et al. (2009), assessing the progression of students' modelling practice, and their related metaknowledge. Data were gathered from observations, concept maps, and interviews. Students' concept maps were analysed using Hmelo-Silver and Azevedo's (2006), structure/behaviour/function framework. Structures refer to parts of a system ("what?"). Behaviours refer to how the structures of a system achieve their outcome ("how?"). Functions refer to the role or output of the system or subsystem ("why?").
The discourse from the observations and interviews underwent qualitative content analysis, based on Schwarz et al. (2009).

Findings

The results present qualitative data from four exemplar students.
We found that the students' understanding of modelling became more sophisticated as the intervention progressed. Thus, for instance, Freddy said: "I would describe a model as a replica of something." In contrast, in his interview, he explained: "For me, models were just a replica of something at the beginning and now you can see that a model can be a kind of statistic or a real habitat in an aquarium and that a film can also be a model. I didn't know that."
Maria described the role of models in scientific exploration, noting that models are important "in science, for example, to write down and secure findings that have been made," and also "for students to learn." Furthermore, she argued "…if I think it's [the model] not enough, I would ask if there are other models somewhere or try to research on the internet to see if I can find out any more information about it. About any diagrams or films."

The students' conceptualization of the coral reef as a complex ecosystem was reflected in their concept maps. Freddy's concept map emphasized the structure dimension, with connections such as: "Sand reefs are covered by coral", and reflected a naïve perception of processes, such as "Coral is food for fish." Daniel presented a more sophisticated perception of the food chain, but still at the level of structure/behaviour: "Sea turtle is one of 7 different species of ocean organism" and "Fish are predators of invertebrates". John's map reflected an environmental narrative at all three dimensions: "Coral reef is ecosystem" (S), "Tourists destroy the corals reefs" (B), "Tourists produce garbage that lead to death of fishes by dynamite fishing" (F). Maria addressed the coral reef at the global level: "Corals live on cliffs in the ocean" (S), "Corals are destroyed by climate change" (B), "Tourists produce garbage that leads to the death of fish by dynamite fishing" (F). Interestingly, some students' concept maps drew connections between their metamodeling knowledge and system behaviour. Daniel, for example, suggested that "Conservationists protect fish" and "Conservationists use models of biodiversity".

Conclusions

The findings indicate that, when given appropriate guidance, students at informal environments are able to shift from considering models as illustrative copies toward models as explanatory tools, developing more sophisticated understanding about the nature and purpose of modelling, and providing more nuanced reasoning during model revision. Our research thus supports the notion that NHMs contribute to students' understanding of ideas in the field of biodiversity and complexity. The use of an authentic environment, which offers learners direct experience with concrete natural phenomena and models in a real, authentic scientific context, allows students to draw upon that experience in order to construct and integrate their knowledge of abstract concepts. Nevertheless, the study also supports Hmelo-Silver and Azevedo's (2006) claim that students must be "scaffolded" for systems thinking.

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Biology, scientific practices, and everyday life situations within an entertaining Mesozoic era setting for young children

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Introduction

Edutainment, which gathered considerable interest already in the 1990's, refers to entertainment that creates opportunities for informal learning by providing information that is educational as well as entertaining (Okan, 2012). Edutainment may be offered through activities like, e.g., walks in nature, games, hobbies, museum visits, or animated cartoons. Research shows that the latter may help children improve their cognitive/behavioral skills, enhance their motivation for learning, reduce their stress/boredom and also familiarize with scientific concepts and problem-solving in scientific ways (Habib & Soliman, 2015; Hanif, 2020).

Many animated series (e.g. 'Sesame Street', 'The Cat in the Hat Knows a Lot about That!', 'Curious George', 'Sid the Science Kid', 'Dinosaur Train', etc.) present young children with science/engineering/mathematics concepts and practices. This paper concerns the 'Dinosaur Train', a top-rated PBS animated series, broadcast worldwide for over a decade. Being so popular with its young audience may have to do with its good education-entertainment balance.

'Dinosaur Train' was developed by a multidisciplinary team and uses an informed Mesozoic era setting, with a train traveling in the Triassic-Jurassic-Cretaceous through a time tunnel, to entertain preschoolers while introducing them to scientific concepts and practices blended with concepts of everyday life (About Dinosaur Train
| PBS KIDS Shows, 2020). Our choice was guided by the fact that it focuses primarily on biological concepts and discusses the nature of scientific research by highlighting scientific practices that may contribute to the enhancement of children's thinking skills. Our study aims at exploring the scientific concepts and practices, as well as the concepts of everyday life introduced in the over 100 episodes aired across the series' five seasons. Here, we present our analysis on the thirty episodes we started with, to address the research questions of (a) which biological concepts, (b) which scientific practices, and (c) which concepts of everyday life are presented to young children through the 'Dinosaur Train' stories and how.

Methods

This paper reports on the content analysis of thirty 'Dinosaur Train' episodes, selected conveniently as they were freely accessible (Table 1). Each episode is about half an hour long and includes two 11-minute stories and a short live-action segment moderated by a palaeontologist' (the latter is out of focus). The leading character is Buddy, a T. rex adopted by a pteranodon family with three more children (Tiny, Shiny, Don), all with different personalities and talents. Each episode begins with the family members being curious about things concerning nature. So, they board the 'Dinosaur Train', which travels through the 'time tunnel' of the Mesozoic era and takes them to different periods in order to meet other species they are curious to learn about. At their destination (Triassic-Jurassic-Cretaceous) they explore/learn about nature, while having fun by joking, playing and singing. On their way back home, they discuss their day and what they've learned in their trip. The analysis of the episodes was performed with the qualitative data analysis software, NVivo. We first coded the content of the episode stories to several subcategories of (a) biological concepts, (b) scientific practices, and (c) everyday life concepts; and then we recorded their frequencies. Some episodes (1/3) were coded independently by the authors, disagreements were discussed, and a satisfactory consensus was reached. Our findings will be thoroughly presented/discussed in the paper. What follows is a brief overview due to word-number limits.

Findings/Discussion

Our findings showed that 'Dinosaur Train' introduces biological concepts that are essential for children's understanding about nature (472 references in 30/30 episodes). The ecosystem, a concept within the capabilities of preschoolers, is presented in a very simplified way, and the idea of its biotic interactions is highlighted through an analogy between the members of an ecosystem and the members of a family which is an already familiar entity. The biotic-abiotic interactions on the other hand, are highlighted through the concept of adaptations. The series is not limited in describing adaptations but also provides explanations through the cross-cutting idea of the structure-function relationship. Since teleology is a persistent bias in children's thinking about nature, the series' choice to provide the 'structure-function' relationship as an appealing alternative, seems a good one.

Plants are presented as living things and biological functions such as growth or reproduction are discussed. However, the overarching 'living-non-living-distinction' on the basis of such functions is absent. The concept of biodiversity is central. The series familiarizes preschoolers with the idea that even species of the same taxonomic group (e.g. ceratopsians) or species related to each other (e.g. different turtle species) can have different body traits. However, the intra-species diversity (a prerequisite for exploring natural selection) is left out of focus. Evolution is presented just once through a merely descriptive example that highlights that the body traits of a species change over very long periods, which may lead to new species. Fossils are presented as the main evidence of such changes, whereas species remains a word, as expected.

The series introduces the scientific practices of asking questions, making/testing hypotheses, making observations and drawing conclusions (412 references in 30/30) as knowledge construction tools, and encourages children to use them in building their own understanding about nature. Finally, the series discusses concepts which are valuable for a fulfilling life, such as emotion management, diversity, friendship, good behaviour, collaboration, encouragement, celebration, competition, perseverance (194 references in 29/30 episodes). Overall, 'Dinosaur Train' seems to be a rich, informal learning resource that might be used to enhance even the standard preschool curricula in ways that have yet to be investigated.

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Season 1		Season 3	
1.1.1	"Valley of the Stygimolochs"	3.5.1	"Classic in the Jurassic: Air, Water & Land"
1.1.2	"Tiny loves fish"	3.5.2	"Desert Day and Night"
1.2.1	"The call of the wild Corythosaurus"	3.7.1	"Solar Train"
1.2.2	"Triceratops for Lunch"	3.7.2	"Bird watching"
1.3.1	"Beating the heat"	3.9.1	"One Big Frog"
1.3.2	"Flowers for Mom"	3.9.2	"Caving with Vlad"
1.4.1	"I'm a T. Rex!"	3.10.1	"Tiny's Fishing Friend"
1.4.2	"Ned the Quadruped"	3.10.2	"Butterflies"
1.11.1	"Derek the Deinonychus"	Season 4	
1.11.2	"Don's Dragonfly"	4.6.1	"Junior Conductor Jamboree"
1.14.1	"The Theropod Club"	4.6.2	"Troodon Train Day"
1.14.2	"Hatching Party"	4.9.1	"What's at the Center of the Earth? Layers!"
1.15.1	"The Old Spinosaurus & the Sea"	4.9.2	"What's at the Center of the Earth? Fossils!"
1.15.2	"A Spiky Tail Tale"	Season 5	
1.16.1	"Night Train"	5.1.1	"The Tiny-saur Train"
1.16.2	"Fossil Fred"	5.1.2	"How Many Horns?"
1.17.1	"Dinosaurs in the snow"	5.2.1	"Mom Was a Kid Once" Part 1
1.17.2	"Cretaceous Conifers"	5.2.2	"Mom Was a Kid Once" Part 2
1.23.1	"Triassic Turtle"	5.4.1	"A Brand New Species" part 1
1.23.2	"Tank's Baby Brother"	5.4.2	"A Brand New Species" part 2
1.24.1	"Erma Eoraptor"	5.6.1	"Love day"
1.24.2	"Under the Volcano"	5.6.2	"A new leaf"
1.27.1	"Iggy Iguanotation"	5.7.1	"Under water Race"
1.27.2	"Shiny Can't Sleep"	5.7.2	"Buddy Wants to Fly"
1.31.1	"The Wing Kings"	5.8.1	"King and Crystal Play Red Rock"
1.31.2	"The Big Mud Pit"	5.8.2	"Nick of Time"
1.34.1	"Elmer Elasmosaurus"		
1.34.2	"Dinosaur Block Party"		
1.35.1	"Carla Cretoxyrhin"		
1.35.2	"Train Trouble"		
1.37.1	"The Amazing Michelinoceras Bros"		
1.37.2	"Dad's Day Out"		
1.38.1	"Great Big Stomping Dinosaur Feet!"		
1.38.2	"Hornucopia!"		
1.39.1	"The Good Mom"		
1.39.2	"Diamond Anniversary"		

Table 1. The thirty episodes *('1.1.1' means season 1/ episode 1/ story 1)*

Exploring the dynamic relationship between a teacher's questions and students' responses about cell membrane biology

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Rationale and key objectives

Because molecular biology deals with the fundamental biochemical interactions that account for, for example, the development of diseases, it has a major impact on people's daily lives. However, school students lack direct experience of molecular processes and may not appreciate the relevance of molecular biology to their lives (cf. Duncan & Boerwinkel, 2018). We aim to contribute to making the field of molecular biology more accessible for students and educators alike and discuss how students' lack of direct experiences with molecular processes can be counteracted by the usage of language, facilitated by a teacher's questions.

In biology we want students to develop their existing conceptions so that the significance and relevance of biological concepts for their daily life becomes clearer. A powerful way to elicit students' conceptions is by questions posed by the teacher, especially during teaching. However, surprisingly little is known about the questions asked by teachers in biology classrooms and how this can facilitate students' thinking.

Kampourakis and Niebert (2018) have proposed a typology of *what*, *why* and *how* questions with regard to their epistemic, ontological and disciplinary (e.g., physiology) status. The idea is that by becoming aware of different types of biological questions, teachers can improve their practice of guiding their students' answers.

Research design and methodology

We report on an episode where one of the authors acts as a teacher to facilitate dialogue between three upper secondary biology students and herself about cells and their membranes. We are guided by the following research question: How can different types of questions be used when teaching molecular biology to enable upper secondary students to appreciate the importance of what they are learning? Based on Kampourakis and Niebert (2018), we identify linguistic forms (e.g., "because" being an answer to "why?") to explore the relationship between the teacher's questions and the statements and explanations developed by the students about cell biological key terms.

In the following, we discuss an excerpt which is taken from early in a conversation about cells and cell membranes between three upper secondary students (Clemens, Lisa[1], Greta, all pseudonyms) and their teacher. The conversation is translated from Norwegian. It centres on a concept cartoon (see Figure 1). The conversation is part of a lesson about cell membranes which lasted about 1.5 hours and was designed by the first author.

[1] Lisa participated more later in the conversation.

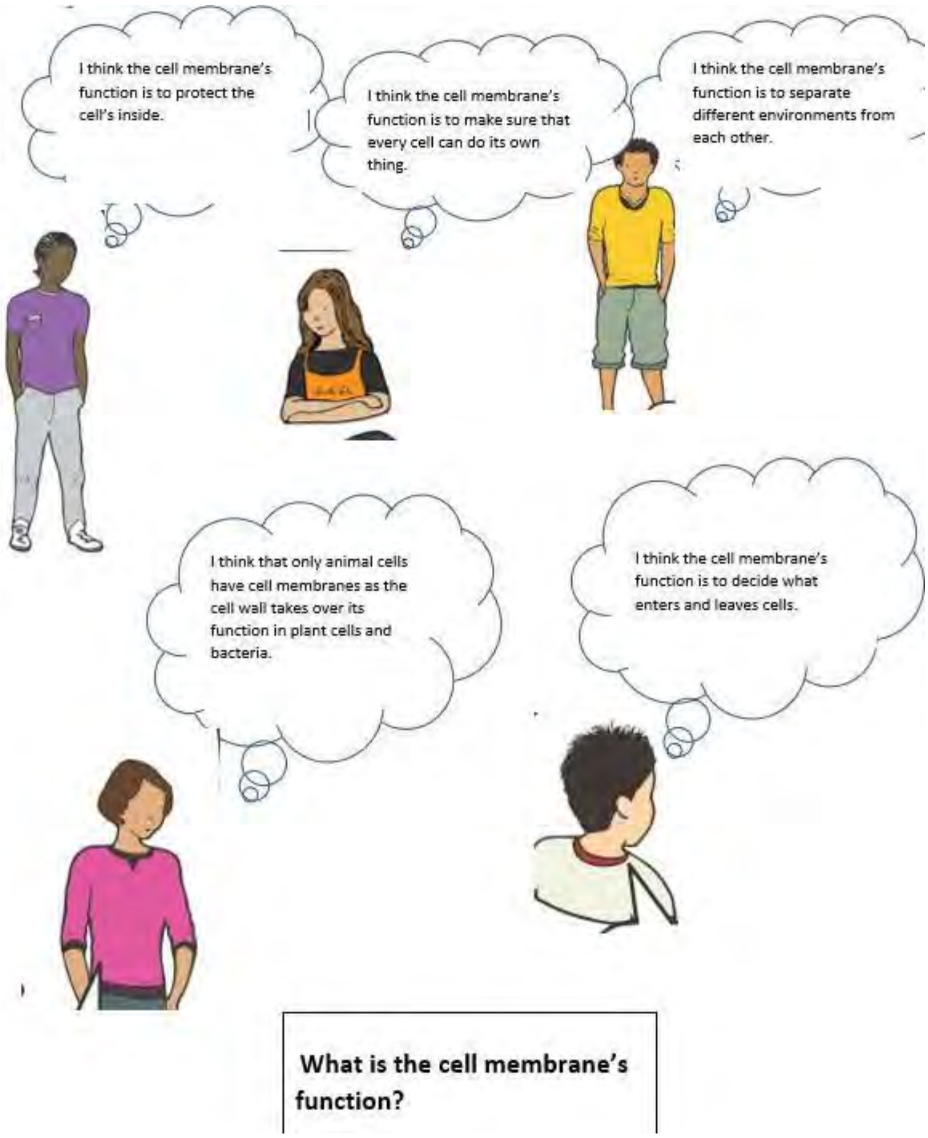

Figure 1 Concept cartoon used as teaching tool for dialogue about cell membranes.

Findings

In this proposal we can only illustrate our findings (for reasons of space). The following dialogue comes immediately after Clemens has commented that plant cells have cell membranes.

1	Teacher (T):	**Why**[2] do you think plant cells also have a cell membrane, Clemens?
2	Clemens:	**I don't know**. Why not? It is logical **that** they have one. The wall to maintain the structure and membrane and stuff [gestures with his hands].
3	T:	**What is the difference** between the wall and the membrane?
4	Clemens:	I have no idea.

[2] Terms which are highlighted in bold indicate units of our analysis, that is key questions asked by the teacher and key terms as identified and discussed during the conversation.

5 T: This girl [in the concept cartoon] says that the cell membrane's function is to make sure that every cell can do its own thing. **What** does she mean by it?

6 Clemens: It is **therefore** (..[3]) well, to **separate** one from cell from another. You have a membrane, and then you have a **cell here and there**. So, you see, they do not mix. I think.

(…[4])

7 T: Now you are talking about cells in a human body, are you not?

8 Greta: That is **like** that automatically. When you talk about cells, **you think of humans first**. But it will be **like** that for multiple organisms.

9 T: Yes, because you said the idea is that cells are separated from other cells?

10 Greta: Yes, that it is **in principle** what we say. (…)

11 T: Do you see this boy □in the concept cartoon□? "I think the cell membrane's task is to decide **what** is transported in and out of the cell." Did you agree with him?

12 Greta and Clemens: Yes.

13 T: **How** does the cell membrane decide?

14 Greta: The cell membrane is the one which has **aquaporins**, or how it is named (..) **Proteins** which have their own ion **channels (**…).

The excerpt shows that it is the teacher who drives the dialogue by means of continuously alternating between different types of questions, namely why, how and what questions (in bold), thus pushing forward the determination and establishment of a shared understanding of some important cell biological concepts and how these relate to an overall theory of cell membrane biology.

To help students gain awareness of their own conceptions, and at the same time establish an understanding of these biological concepts, the teacher asks the students to identify the *difference* between cell walls and membranes (contribution 3). In doing so, she requires the students to display a higher level of understanding than would be the case if they were simply asked to state properties of cell walls and membranes.

Conclusions

For a biology teacher concerned to support students' learning, it can be very effective to ask students to compare the structures and functions of the various structures found at various levels within organisms. Here, we have concentrated on how, when doing this, a complex issue (the function of the cell membrane) can be broken down into its components, with relevant information distinguished from less relevant information (cf. Allen & Tanner, 2002).

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[3] Two dots indicate that the student paused to think.

[4] Three dots indicate omitted material.

Scientific Inquiry / Field Work

Two short interventions promoting abstract thinking and control-of-variables reasoning schemes improve seventh graders' achievements in biology

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Theoretical background, biological topic, research rationale, and key objectives

The major goals of the biology curriculum in junior high school include acquiring knowledge and understanding related to this content domain, in addition to the development of critical thinking and the understanding of complex systems such as ecosystems (e.g., Israeli Ministry of Education, 2023). It is well documented that learning biology is difficult for many students (e. g., Chi, 2005; Cohen & Yarden, 2009, 2010; Vijapurkar, Kawalkar, & Nambiar, 2014; Fernández & Jiménez Tejada, 2019; Vlaardingerbroek, Taylor, & Bale, 2014; Verhoeff, Waarlo, & Boersma, 2008)

We addressed students' difficulties in biology in junior high school from the cognitive development perspective. According to Piaget, advanced reasoning schemes such as abstract thinking and control of variables develop during the formal operational stage. Therefore, students' low cognitive levels could explain difficulties in biology topics that demand such schemes. Recent studies have indicated that more than 80% of seventh graders have not reached the formal operational stage (e.g., Babai & Levit-Dori, 2009; Shayer, Ginsburg, & Coe, 2007).

Here we explored whether two short interventions aimed at accelerating both the abstract reasoning and the control-of-variables reasoning schemes, using several lessons from the Cognitive Acceleration through Science Education (CASE) program (Adey, Shayer, & Yates, 2001) would have a positive effect on seventh graders' academic achievements in relevant topics in biology. We were motivated by the study of Babai and Levit-Dori (2009) that showed that a short intervention using CASE lessons aimed at accelerating the control-of-variables reasoning scheme improved students' control-of-variables abilities.

The full CASE program of 30 lessons is known to have a positive effect on students' academic achievements. Here we assess whether using five lessons that each focus on either the abstract reasoning or control-of-variables reasoning scheme would also have a positive effect. While the curriculum under study does not allow the delivery of the entire CASE program, short interventions that use only several lessons focusing on specific and relevant reasoning schemes could be considered.

Research design and methodology

Participants in the study were 263 seventh graders. Half of the classes (*n*=133) were randomly chosen to serve as an intervention group and the other half (*n*=130) as a control group. The two groups had similar academic achievements in science (assessed by a science pretest) prior to the intervention.

In the first stage we determined the cognitive level of each student by a validated assessment test (e.g., Adey et al., 2001; Babai & Levit-Dori, 2009; Shayer et al., 2007). In the second stage a short intervention aimed at accelerating the abstract reasoning scheme was given only in the intervention group (CASE lessons 23, 24, 25; 90 min each). In the third stage the subject of the cell was taught for four lessons (45 min each) in a similar way in both groups and a final exam on the topic of the cell was given. In the fourth stage a short intervention aimed at accelerating the control-of-variables reasoning scheme was given only to the intervention group (CASE lessons: 1, 2; 90 min each). In the fifth stage the topic of ecology was taught for 12 lessons (45 min each) in a similar way in both groups and a final exam in this topic took place. Toward the end of the academic year a general science test that included all the scientific topics that were studied during the year was administered.

Findings and discussion

The results are presented in Table 1 and Figures 1 and 2.

Table 1. Distribution of cognitive levels in the research population

Cognitive level	Number of students			Percent in population [%]
	Control group	Intervention group	Total population	
Below formal operational stage	116	121	237	90.1
Formal operational stage	14	12	26	9.9

The findings indicated that only about 10% of the population had reached the Piagetian formal operational stage. This is in line with the study rationale and previous findings (e.g., Babai & Levit-Dori, 2009; Shayer et al., 2007).

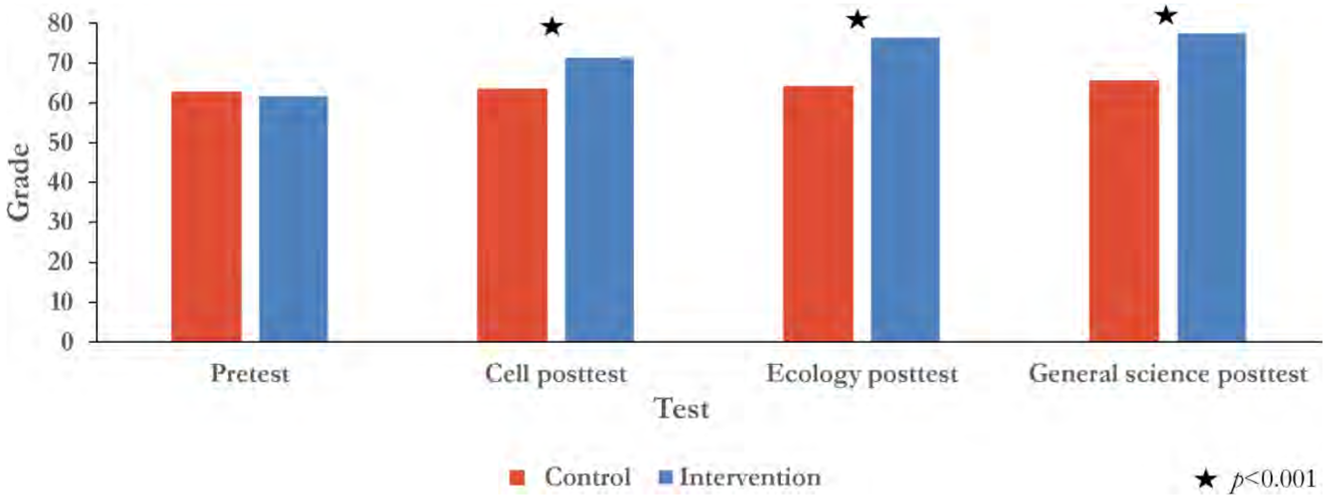

Figure 1. Pretest and posttests mean grades in the control and intervention groups

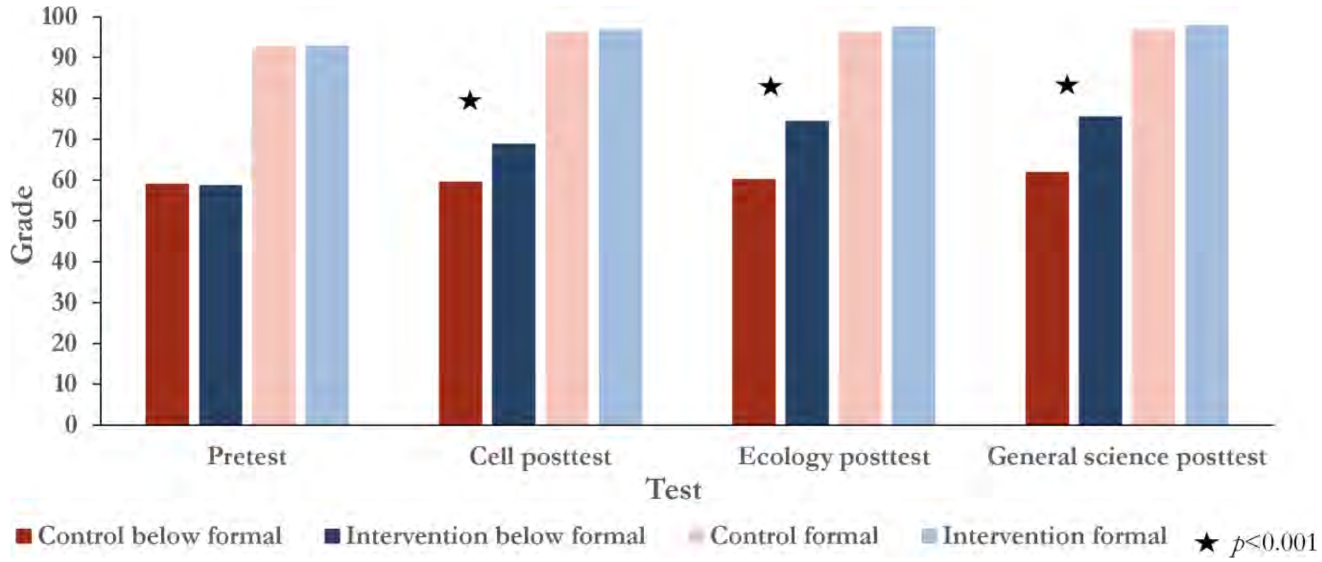

Figure 2. Pretest and posttests mean grades for students at the formal operational stage or below in the control and intervention groups

Comparison of the pretest grades revealed no differences between the groups. However, the abstract reasoning scheme intervention had a significant positive effect on students' achievements in the cell posttest, both for the entire population (8% difference; t=7.84, df=261, p<0.001) and for the subpopulation of students found below the formal operational stage (9% difference; t=9.24, df=235, p<0.001). following the addition of the control of variables reasoning scheme intervention, a significant positive effect on students' achievements was found in the ecology posttest, both for the entire population (12% difference; t=12.40, df=261, p<0.001) and for the subpopulation of students found below the formal operational stage (14% difference; t=14.18, df=235, p<0.001). A significant positive effect on students' achievements in the general science posttest was also observed for the entire population (12% difference; t=11.95, df=261, p<0.001) and for the subpopulation of students who are below the formal operational stage only (14% difference; t=13.71, df=235, p<0.001).

Overall the findings are in line with the study rationale, as statistical differences between the intervention group and the control group were detected for the entire population as well as for students who were below the operational cognitive stage. In addition, in line with the study hypothesis, students in the formal operational stage outperformed their peers in all tests carried out during the study (28% to 34% difference; p<0.001 for all tests).

The study shows that the two short CASE interventions significantly affected students' achievements in biology topics that were studied here and in a general science test. Such effects were evident for the vast majority of students (90%), who had not reached the formal operational stage. We suggest taking into account the cognitive levels of students. We also recommend that science educators pay attention to limitations related to students' cognitive levels and employ ways of overcoming these obstacles to learning.

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Biology Undergraduates Internship Combining Lab Training and Making Learning Video

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Rationale
Internship of students from countries suffering from war at the laboratories of leading world universities aims not only to acquire new experiences and knowledge but also to share them with students at a home university. The task of knowledge sharing requires students to have a deep understanding of the course material and to improve their communication skills. Visual references are considered a valuable creative practice [8]. Videos are vital for biological disciplines, where laboratory equipment is expensive and methods are complicated [6,7]. The involvement of students in making visual learning tools is not new [3], but sharing knowledge via self-made videos makes it more engaging [4]. The benefits of student-produced videos are creativity and collaboration [5], improvement of skills in problem-solving, presentation, collaborative work, and the ability to discover principles and concepts [1], while the relationship between creativity and academic motivation is disputable [2].

Objectives
- Define the place of video-making among other creative activities in a biology classroom.
- Reveal the influence of video-making on students' academic performance.
- Study the impact of video-making on students' motivation.
-

Research design and methodology
The case study was conducted on the basis of a two-month exchange program for Ukrainian students at Ruhr-University Bochum, Germany. The students were mastering lab practices and capturing videos of lab procedures.
Students' written reports, presentations, and supervisors' semi-formalized characteristics of students' achievements were used as indicators of academic performance.
Students answered the questionnaire about their impression of the training program and its influence on their further study.

Findings
Ten Biology students from Kyiv National University had training in the laboratories of Molecular Embryology, Developmental Biology, Cellular Biology, and Human Genetics. They also had a workshop on using video-editing apps Shotcut and DaVinci Resolve. Students have created 16 learning videos estimated as suitable for learning purposes. Their academic performance average score was 94, 7 (the maximum possible is 100). Supervisors mentioned that students did well in individual and group work, were highly motivated, possessed necessary biological and communicative skills, and expressed enthusiasm, creativity, and independence.
The main reasons for students participating in the project were acquiring “Professional development, new knowledge, and skills” (6 respondents), “International experience” (5 respondents), and “Personal challenges” (5 respondents).
Students mainly estimated the training as successful and goals as achieved. Up to 90% of students agreed that the training was well-prepared and had an engaging design. A friendly educational environment and respectfulness toward the students promoted their learning and video-making (80-90% strongly agreed answers).

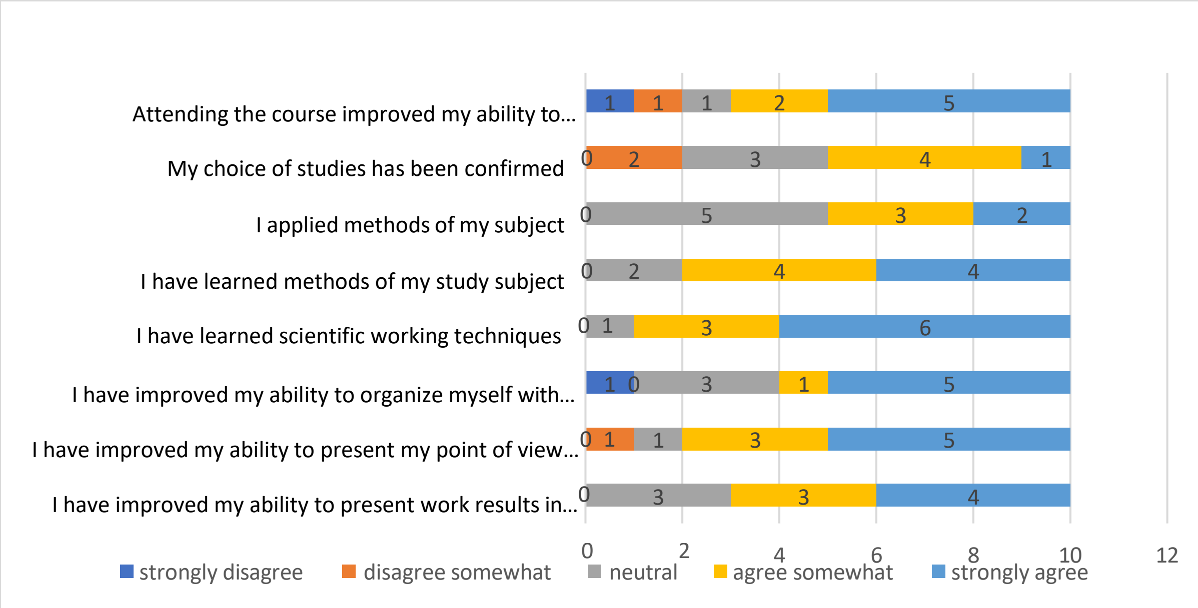

Fig.1. Students' self-reflection on the impact of the internship.

The acquisition of lab techniques and science communication appeared the most valuable (Fig.1). However, for 60% of students, the research methods they studied were not directly applicable to their current field of study, causing them to doubt their choice of course, which shows reflective and critical thinking. Students' perception of the internship outcomes is shown in Fig.2.

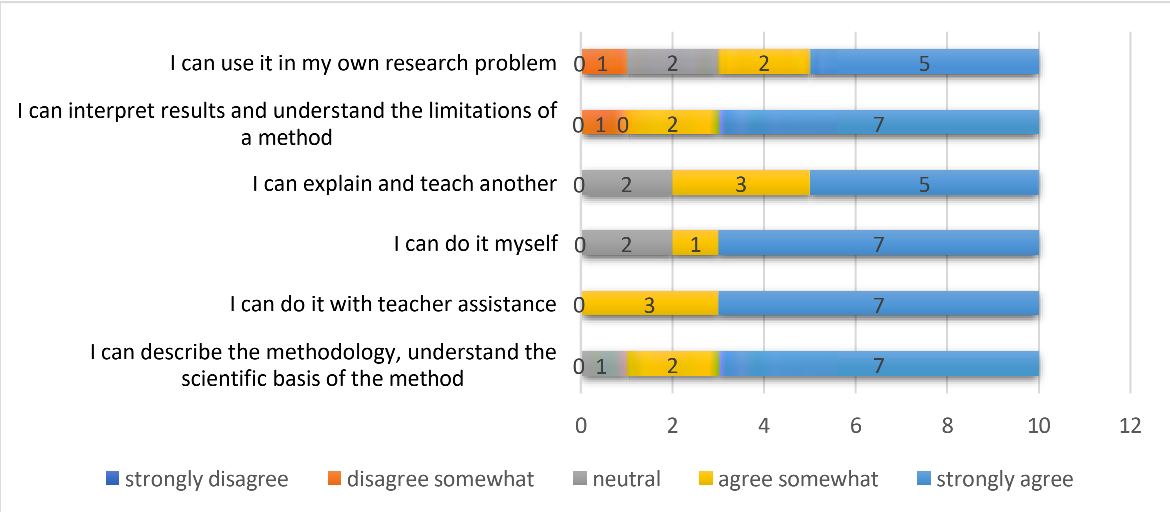

Fig.2. How confident are students in the experimental methods?

Students assumed the lab skills as the most valuable things acquired during the training. Biological knowledge was at the second position, and scientific writing skills shared the third position with social/ intercultural skills. These skills are estimated to be more useful in professional work (7 answers) than for course/diploma projects or completing the next educational level (3 answers in both).

Three of ten students were sure that making videos promotes memorizing, the other three - that it contributes to a deeper understanding of lab methods, and three students found this activity not helpful for studying Biology. Only one student recognized these skills as essential for teaching as a future job. Here is some contradiction with the emotional reflection of creating videos. Students were excited that they were able to do it: "Making videos is great!", "It opens a new sight in Biology" was a typical reaction.

Conclusions

Students' lab reports could be presented not only as text illustrated with their own drawings or diagrams but also accompanied by video records. This creative activity does not require professional technics and extra time. It helps in memorizing laboratory procedures and understanding their scientific background, but its influence on motivation was ambiguous. It does not distract students from solving biological tasks but does not motivate them to develop video-making skills and weakly influences their interest in teaching. However, the effect is positive regarding communicative skills, intrinsic goal orientation, task value, and expectancy components.

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The DAFFODIL DNA project: developing an model of collaborative inquiry

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Theoretical background or rationale
Inquiry and the understanding of the nature of science are deeply intertwined. Since the systematic review of inquiry-based learning by Kirschner, Sweller & Clark (2006), and subsequent curriculum reforms inquiry-based learning in the UK has fallen out of favour as an ineffective classroom tool. However, there are other benefits to inquiry-based learning that were not discussed, namely the psychological energy (Bevans & Price, 2016) that learners develop as a result of the identity and intrinsic rewards of success in learning a new technique or obtaining valid data. This energy is often seen by practitioners as motivation in the classroom, but how this maintains over a longer period of time is may be linked to the aspirations of the students as much as the enthusiasm and knowledge of the teacher. Therefore how inquiry-based learning needs to consider the development of the scientific identity as much as the conceptual learning for it to have a lasting impact on learners and their steps towards the pipeline of scientists.

This projects builds upon the successful Jersey Daffodil Project (Hale, 2020; Hale, Harkess and Könyves, in review) to explore whether the benefits of authentic inquiry of a greater sense of academic agency, the opportunities to gain expertise, challenge their preconceptions, enhancement of their relationship to science and improvement in their academic attainment (Rivera Maulucci et al. 2014) could be developed in different contexts in parallel. The Daffodil DNA Project thereby brings a model of collaboration between students, teachers, scientists and different schools for a common and achievable goal.

Key objectives:
1. To identify and assess any value of sustained authentic project work impact on post-16 student aspirations related to STEM fields.
2. To identify and assess the value of context-based project work on the domain specific knowledge of post-16 students.
3. To determine whether sustained project work has a positive effect on student STEM values.

Research design and methodology:
Six schools were recruited during February 2021with a further two joining via word of mouth in February 2022 to the Daffodil DNA Project. Each school received a grant of approximately
£3000 from the Royal Society through the Partnership Grants scheme to purchase a Oxford Nanopore MinION DNA sequencer, a thermocycler, electrophoresis tank and consumables. Teachers and technicians then attended a training day at the University of Dundee. Each school then received 2 daffodil cultivars to attempt to sequence the chloroplast genomes using the MinION using the techniques learnt. Regular online meetings were provided for teachers to collaborate and support each other, with in-person collaborations during the wet-lab phase between schools and their partnering scientists.
Data was analysed in parallel allowing students the opportunity to assemble the chloroplast genomes that they had sequenced. Using the same student generated data, a higher quality assembly was completed by the University of Dundee bioinformatics group.

The impact of the project was determined via pre- and post-project online questionnaires for students, pre- and post-project interviews for teachers and scientists.

Findings:
The project has demonstrated that novel science using cutting edge technology can take place in the classroom. As seen in figure 1, as an example, the quality of data produced by students is phenomenal. To date 14 draft chloroplast genomes have been obtained in varying degrees of completeness. This data has been deposited within the European Nucleotide Archive with the students as authors.

Preliminary analysis of the student questionnaires is showing a positive effect on student attitudes towards STEM subjects and aspirations. Similarly teacher interviews have shown that they are modelling the behaviour of a scientist within their lessons, not just during the project run-through. In addition, the scientists that were working outside of their expertise also identified the positive impact of sustained engagement with a small number of students led to themselves developing more psychological energy for their own endeavours as they felt more valued as scientists.

Conclusions:
There are many potential explanations for the benefits of this project to students. Due to the collaborative nature of the inquiry where no stakeholders held the knowledge of the project, each individual brought skills, knowledge and attributes that were valued in each and every school. The fact that there are no model answers meant that this was a genuinely authentic inquiry where whatever data the students, teachers and scientists produced would be new to science. This is likely to have increased the psychological energy and identity as scientists among all involved. This energy within the teachers underpins the success of the project in their own contexts. Therefore when considering how inquiry can be successfully enacted in the classroom, it will remain key that teachers are provided enough support whilst maintaining autonomy to ensure that they have the psychological energy to meet the needs of each learner in the classroom.

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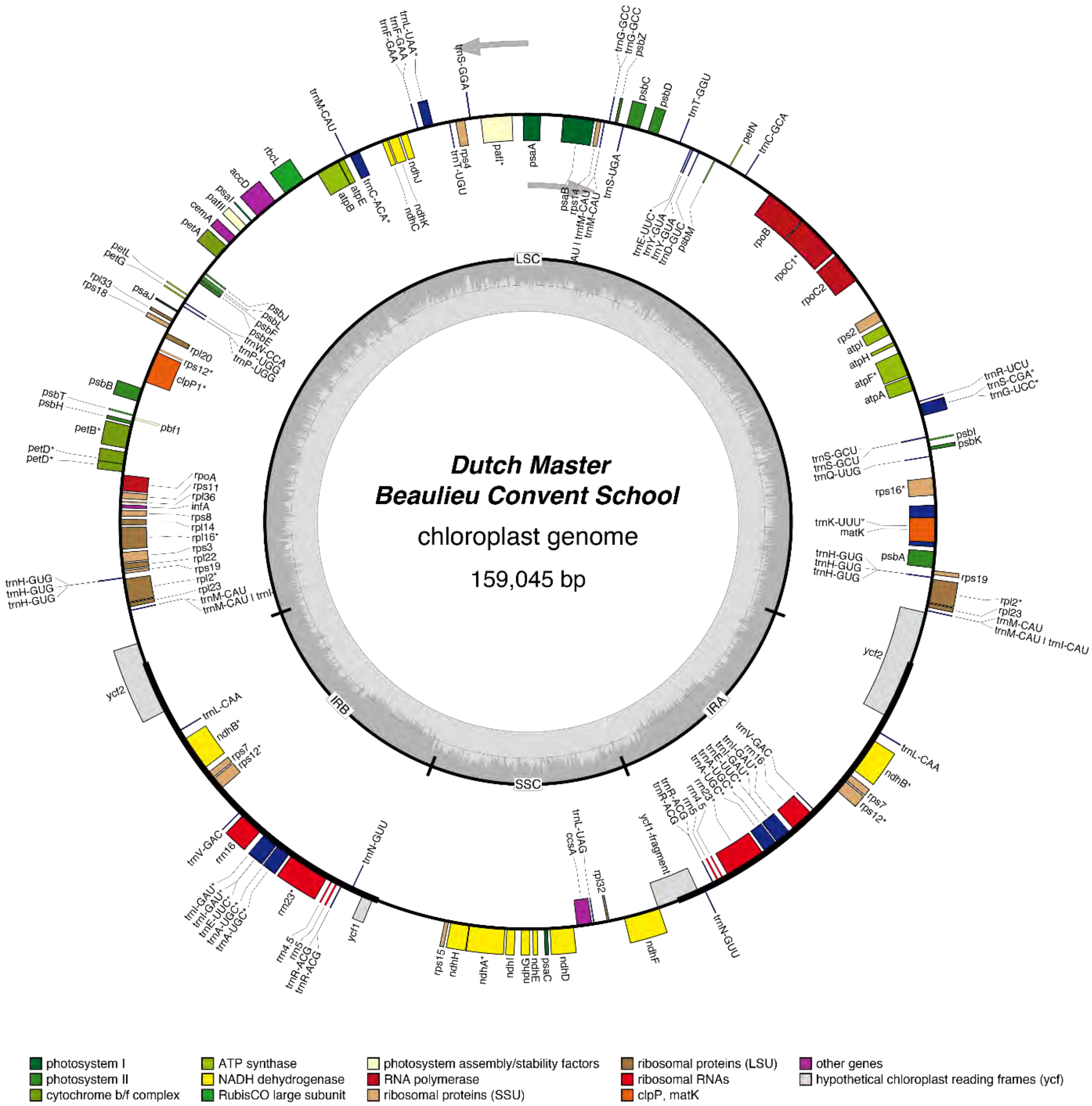

Figure 1. An example chloroplast genome, mapped and annotated following data obtained by students of Beaulieu Convent School. The Dutch Master cultivar was supplied by Grampian Growers and had previously had no DNA sequences attributed to it.

What do teachers think about fieldworks in biology teaching and professional development? A study in southern colombia

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THEORETICAL FRAMEWORK:
Fieldwork can be considered as a teaching strategy in the natural sciences where students have to use specific knowledge, procedures, abilities and skills to solve scientific problems related to Biology (Tal y Morag, 2013; Lavie Alon y Tal, 2016;). We consider that they acquire a special value in the teaching and learning of Biology because they allow students to approach their object of study, "the living", as close as possible to their natural conditions. They also make a systemic and holistic perspective that allows them to understand the relationships that make up the living phenomenon in conjunction with its environment: trophic networks, adaptations, inter and intra-specific relationships, biodiversity, ecosystems, autopoiesis, etc (Hamilton-Ekeke, 2007; Rennie, 2014). Nevertheless, they also offer high-value educational opportunities related to procedural and attitudinal aspects, such as the appreciation of the meaning of nature, the valuation, conservation, sustainable enjoyment of natural resources. According to Behrendt and Franklin (2014), preservice and active teachers do not have sufficient preparation on how to teach in nature, because neither the initial training courses nor the permanent training courses have allowed them to develop an adequate knowledge of the content and didactics necessary to teaching outside of school in natural settings. That is, how to design and carry out Field Practices with the students (Amórtegui, Mayoral & Gavidia, 2017).

Key Objective:
Characterize the conceptions about fieldworks in biology teaching and professional development constructed by active science teachers in the Huila region.

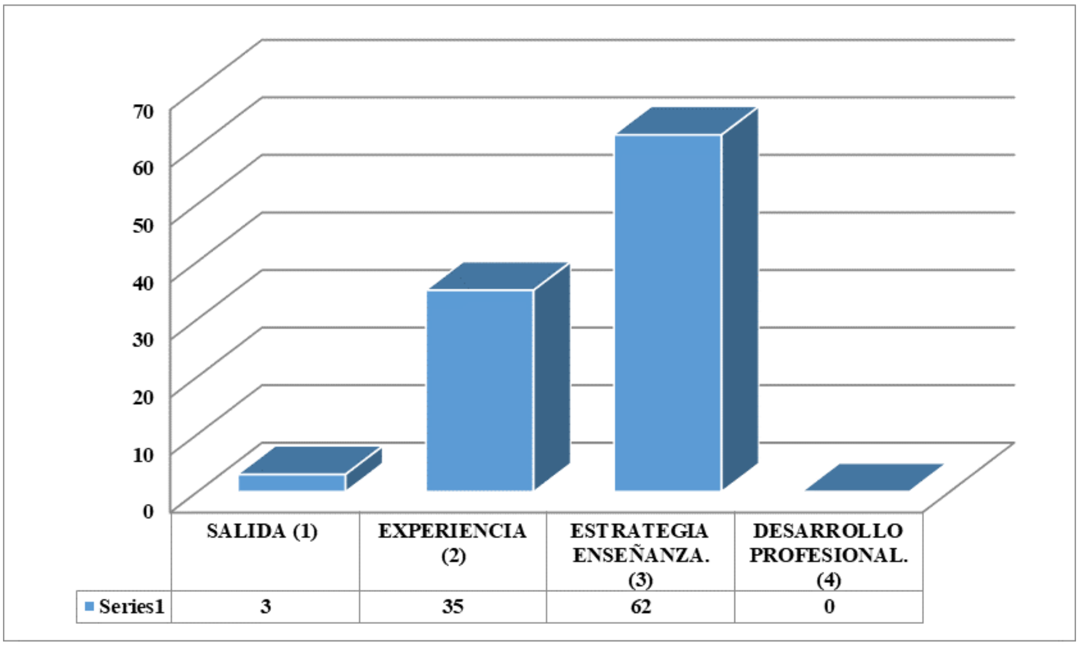
Research Design and Methodology:
The study addresses a mixed, prospective research with quantitative and qualitative contributions, developed during the second semester of 2020. Quantitatively we have used a pre- and post-test through the application of a previously validated questionnaire consisting of 12 open questions. Due to the COViD 19 pandemic, we applied the questionnaire through the platform Google Forms. For their analysis, we have used the software IBM SPSS 22. In relation to the qualitative analysis, we have used the software Atlas.Ti 7.0. The study population consisted of 100 active publics' high school science teachers of the Huila region. The population has work experience which ranges from less than five years with 69 teachers (69%), of which 42 are men and 27 women. There are also 19 teachers with experience between 6 and 10 years (19%) grouping in these category 11 men and 8 women; the remaining 12% corresponds to twelve teachers with experience of more than 10 years, of which seven are men and five are women. For the systematization of the information, we followed the proposal of the category system proposed by Amórtegui (2018).

Findings:
This is the Normal style (Times New Roman, 12 points, 6 point space after paragraphs, line spacing 1.15, justified). For the case of this paper, we present the findings in the conceptions of the professors for the *Nature Fieldwork*.

Nature Fieldwork

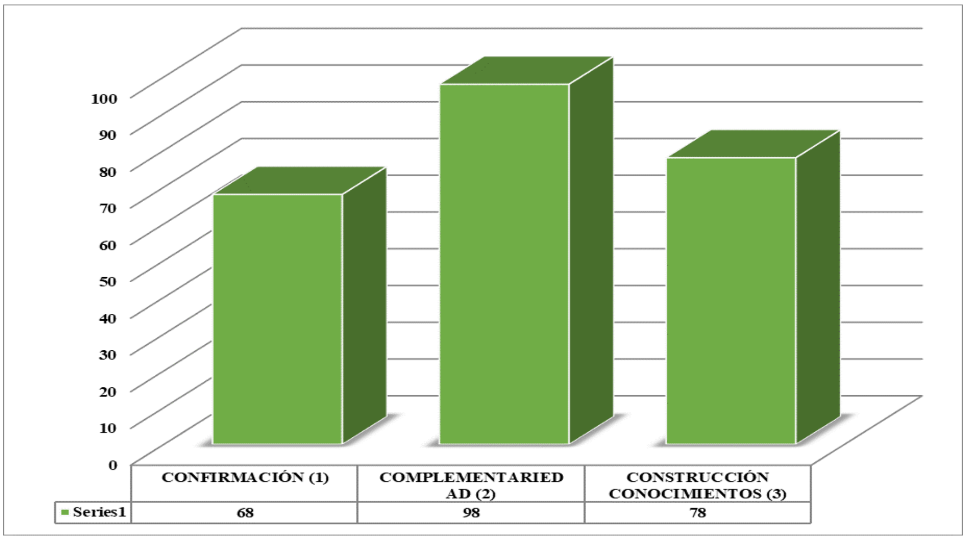
In this first category, we use two guiding questions. The first was, *what is a Fieldwork?* Managing to identify four subcategories of analysis in the teachers' responses (Graph 1).

In other words, for these practicing teachers, field works are mainly a teaching strategy (62 teachers), which can be coupled with science education. However, it is clear that there are few who consider that the use of a field trip or other practical work contributes in the same way, to their Knowledge and Professional Development. Then, the level of response of the participants is acceptable, but it is not ideal, even more so, when there are teachers with many years of experience and work practice in the sample.



Faced with this, Morag and Tal (2012) and Moral, Tal and Rotem-Keren (2013) affirm that the types of natural environments and field trips are diverse. For these authors, they are different in several ways; they differ if it is a visit to a museum, planetariums or science centers, since they allow direct experience with the real phenomena of nature. Similarly, they consider that a Field Practice provides more training elements than any other extra-school activity. Field practice in natural settings has the potential to improve pro-environmental behavior and conservation awareness. They are even favorable in the well-being and health of the human being, as a space for physical activity (Brymer, Cuddihy and Sharma-Brymer, 2010).

The second question was, *what relationships do you find between the Fieldworks and the topics covered in the Natural Sciences classes*? In which three subcategories were recognized around the responses of the male and female teachers (Graph 2).



In this sense, Tal (2006) affirms that those teachers with more experience in fieldwork develop greater pedagogical skills, while those with less experience tend to carry out directed activities and have inadequate content knowledge, in addition to fulfill roles of greater authoritarianism in front of their students.

Conclusions:

In the first measure, the degree of appropriation that natural science teachers in the region have to define a Fieldwork is highlighted. It is evident that they know about the functionality of this type of Practical Work and that they have also put it into action. However, it is clear that they do not recognize the contribution of this type of strategies to Professional development and their Professional Knowledge. Which leads us to think that initial training programs in the region suffer from certain competences oriented to pedagogical knowledge, to the dignity of teaching work and to the components of Pedagogical Content Knowledge (PCK). Therefore, it is necessary to review the teacher training curricula in the region and link to these, strategies focused on the conscious and reflective use of strategies such as Field Trips.

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Socioscientific Issues and activism

Attitudes of biology students towards animal experimentation and nonhuman primate research

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Theoretical background or rationale:
Animal experimentation (AE) and nonhuman primate (NHP) research are controversially discussed socioscientific issues (SSIs). Attitudes towards these issues range from absolute rejection to convinced acceptance (Sandgren et al., 2020). Such diverse learning dispositions can enhance or reduce the learner's willingness to deal with SSIs (Kremer et al., 2019). Hence, knowing about attitudes towards AE and NHP research is significant for designing biology education measures.
Attitude formation is influenced by extrinsic and intrinsic factors (Ajzen & Fishbein, 2000). Regarding attitudes towards AE and NHP research, extrinsic factors are, for instance, the specific research context or the test animal (France & Birdsall, 2015). Medical or behavioural research influence attitudes positively, whereas research with NHPs is viewed most negatively (Sandgren et al., 2020). Knowledge is a decisive intrinsic factor underlying attitudes, although ethical aspects can be more influential regarding AE research (Garrecht et al., 2021; Hößle & Alfs, 2014). Emotions play a particularly important role in extreme stances (France & Birdsall, 2015).
So far, few studies explore attitudes towards AE in specific research contexts, particularly regarding behavioral research. However, there are research gaps in understanding attitudes towards AE with NHPs, AE with other test animals, and behavioural research with NHPs.

Key objectives:
Therefore, key objectives are

(1) In which way are approving, disapproving, and other attitudes present among biology students towards AE with NHPs, AE with other test animals, and behavioural research with NHPs?
(2) In which way do intrinsic factors (knowledge, ethical aspects, emotions) underlie these attitudes?

Research design and methodology:
We address these questions with an online questionnaire study that comprises data from 503 biology students (287 monobiology students, 216 pre-service teachers with biology as a subject). Data is collected from five different German universities. Qualitative data is analysed using content analysis (Mayring & Fenzl, 2019). A specific coding manual is developed, based on, e.g., the SEE-SEP model (Chang Rundgren & Rundgren, 2010) that has already been applied to the issue of AE research (Garrecht et al., 2021). Quantitatively, the importance of emotions connected to the three research contexts is analysed (Wilcoxon signed-rank test), as well the quality of emotions that participants connect with each context (rm*ANOVA*).

Findings:
The study shows that extrinsic factors, such as research context and test animals, influence attitudes. Attitudes towards AE with NHPs are most negative. Descriptively, attitudes towards AE with other test animals are more positive. With half of all participants being in favor of behavioural biology with NHPs, there are most positive attitudes concerning this context.
Regarding intrinsic factors, attitudes are most associated with knowledge. For instance, 60% of participants use science knowledge to explain their attitudes towards AE with NHPs. About a quarter of participants connect ethical aspects to their attitudes, although the ethical dimension is more influential regarding AE contexts than regarding behavioural biology.
Emotions are significantly more important for AE with NHPs than for behavioural biology with NHPs (z=-3.402, p<.001, r=.114) and for AE with other test animals (z=-3.249, p<.001, r=.109). The mean quality of emotions showed a statistically significant difference between research contexts, F(1.61, 351.014)= 238.587, p<.001, ηp^2 = .372. Post-hoc analysis revealed significantly (p<.001) more negative emotions for AE with NHPs than for AE with other test animals (*MDiff* =-.305, 95%-CI[-.385, -.226]) and for behavioural biology with NHPs (*MDiff* =-
.993, 95%-CI[-1.116, -.869]).

Conclusions:

The study addresses gaps in research on attitudes towards AE and NHP research and their influencing factors. Results show that attitudes are influenced by extrinsic factors (research context and test animals). The context of AE research is connected to more negative attitudes, compared to behavioural biology (France & Birdsall, 2015). Also, the use of NHPs as test animals is viewed most critically, due to the animals' resemblance to humans (Sandgren et al., 2020). Knowledge, especially in science, is the primary intrinsic factor underlying attitudes. Ethical aspects play a greater role in AE research, compared to behavioural biology (Hößle & Alfs, 2014). Emotions are significant across all stances, with negative emotions prevailing in AE with NHPs.

These findings aid the design of target group specific biology education measures. For an in- depth analysis of the interaction of different factors, an interview study is conducted, focussing on subjective theories. Ultimately, results are used to design guidelines for teaching affectively challenging SSIs in biology classrooms.

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NOS aspects discussed by biology teachers in the context of evolution and faith

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Rationale and Theoretical Background

There is worldwide agreement that evolution is an important subject in science teaching. This study took place in Israel, where high school students majoring in biology represent various ethnic and religious groups. Despite being a mandatory topic, student performance in evolution questions in the matriculation exams is suboptimal. This is in accord with prior studies pointing to theological and pedagogical difficulties in teaching and learning evolution, some of which result from apparent contradiction between evolution and faith (Siani &Yarden, 2020).

Earlier, we found that biology-education experts agree that any attempt to challenge these difficulties must include discussion of the nature of science (NOS) (Authors, 2022). This may have a double benefit: developing deeper understanding of NOS and improving evolution education (Nelson et al., 2019). It may also contribute to increase the trust in science by understanding the way science is done, and the ways in which scientific knowledge differs from other forms of knowledge such as religious faith (Reiss, 2010). Explicit instruction of NOS is important in achieving these goals (Abd-El-Khalick & Lederman, 2000), and thus it requires to identify the opportunities in which NOS can be integrated in evolution education aiming to challenge religious difficulties.

The Family Resemblance Approach (FRA) has guided the analysis of the participants' NOS understanding. FRA has been widely used in science education since it offers a holistic view of the complex relationships between many factors in science. FRA describes science as based on two distinct categories: (a) cognitive- epistemic and (b) social-institutional. Science as a cognitive-epistemic system includes aims and values, scientific practices, methods/methodological rules, and scientific knowledge. Science as a socio-institutional system includes professional activities, scientific ethos, social certification and dissemination, social values of science, and political power structures (Dagher & Erduran, 2016).

The key objective of this research is to identify the aspects of the Nature of Science (NOS) that biology teachers address in the discourse about evolution and faith.

Research design and methodology

Based on previous research (Authors, 2022), our research group has developed an interactive learning unit on evolution and faith, framed by the Pedagogy of Difference (Alexander, 2017) which is a novel way to cope with educational challenges related to theological issues.

Topics included: constructing scientific theory, duration and mechanism of evolution, religious approaches to evolution, etc. Each section of the unit was focused on a question, through activities dealing with NOS and religious texts. It was experimented in a 30-hour professional development (PD). Altogether, 18 Jewish and one Muslim biology teachers participated in the PD. The teachers were diverse in term of their own and their students' religious observance.

Data sources were (a) participants' written answers to open questions posed in the unit; (b) observations during the PD meetings. Analysis included content and discourse analysis using the Family Resemblance Approach (FRA) as an analytical framework.

Findings
While most teachers were initially unaware of formal NOS aspects outlined in the national biology curriculum, explicit NOS aspects emerged in the PD discourse. *"In past years, teachers taught how experiments were done and how scientific knowledge was constructed"* (R.M).

Notably, we found that most of the references to NOS in the context of evolution education and religious faith were associated with the Cognitive-Epistemic aspects of NOS according to the FRA (Dagher & Erduran, 2016):

Aims and values: *"Science deals with 'the question of how' and faith is about 'the question of why"* (Y.N).
Scientific practices: "*Scientific explanations are based on empirical evidence*" (E.B.D).

Methods and methodological rules: "*As technology advances more genetic evidence is accumulating for resemblance between different species* " (L.N)

Scientific knowledge: "*Evolution is like a puzzle, we have pieces of information from different sources that slowly integrate and contribute to the understanding of the bigger picture of evolutionary development*" (T.S).

Few statements addressed the social-institutional aspects of NOS, in the category of social certification and dissemination *"The theory of evolution is based on multiple evidence over many years and have been accepted by leading researchers in the world who have examined it"* (T.P).

Conclusions
The study reveals inadequate awareness of teachers regarding formal NOS aspects. However, the discourse during the PD unintentionally touched upon NOS elements related to belief and scientific evidence. The findings emphasize the importance of explicit NOS discussions in evolution education, particularly in the context of religious conflicts. Such discussions can contribute to students' understanding of the distinctions between science and other ways of knowing, fostering a deeper appreciation for the scientific method (Reiss, 2010). Evolution education serves as a valuable opportunity to teach NOS aspects, transcending religious beliefs and providing a foundation for refining scientific theories through empirical evidence (Nelson et al., 2019).

Implications and Future directions
Insights from the study can inform the development of similar units tailored for diverse student populations, including Muslim students. Policymakers and teacher educators can leverage these findings to advocate for the explicit teaching of NOS in evolution education, promoting a more nuanced and inclusive understanding of science in the context of diverse belief systems.

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Teaching infectious diseases at middle schools in the aftermath of COVID-19

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Theoretical background and rationale

Teaching infectious diseases is an integral and important part of the biology curriculum. Previously, infectious diseases were not given much attention in biology education and within biology education research (Byrne, Marston, and Grace, 2021; Jones and Rua, 2008). Considering the recent COVID-19 pandemic there is reason to believe that this topic gained priority in biology tutoring. This study investigated the way Swedish middle school teachers taught infectious diseases in the aftermath of COVID-19 by using the contagion literacy framework (CL) as the analytical tool.

The CL framework was originally developed by Kilstadius and Gericke (2017) based on Nutbeam's (1998) health literacy framework and conceptualize what knowledge pertaining to health and disease that is considered essential for a citizen to understand and hence to be included in the biology curriculum of compulsory schools. The CL framework covers six principal content themes: (i) contagions, (ii) modes of transmission, (iii) infectious diseases,
(iv) hygiene practices, (v) vaccinations, and (vi) antibiotics and antibiotic resistance. The six themes are further subdivided into three levels of health literacy, functional health literacy, encompassing fundamental concepts and knowledge. The subsequent level, interactive health literacy, represents the translation of functional health literacy into practical actions and behaviours. The third level, critical health literacy, involves the utilization of insights into infectious diseases in the everyday decision-making process and the capacity to influence one's lifestyle choices accordingly.

Key objectives

The aim of this study was to investigate Swedish middle school teachers' reflections on their teaching of infectious diseases in the aftermath of the COVID-19 pandemic. The following research questions guided the study:

1) What are teachers' reflections on their adaptations of their teaching of infectious diseases as a consequence of the COVID-19 pandemic?
2) in the aftermath of COVID-19 How can teachers tutoring infectious diseases be described in relation to the contagion literacy framework?

Design and methodology

Methodology was based on individual, semi-structured interviews, as outlined by Kvale and Brinkman (2015). The use of open-ended questions was deliberate, as it afforded the participating middle school teachers the latitude to center their discourse on facets of the knowledge domain that they deemed significant and were inclined to discuss.

Participants were middle school teachers belonging to different schools within the Swedish compulsory school system. The eight teachers (5 biology, 3 civics/history), seven females and one male belonged to five different schools at three different municipals in the southwest part of Sweden. Middle school teachers were chosen because at this educational stage course contents about health and disease are introduced into the biology syllabus of the Swedish national curriculum. All interviews were transcribed verbatim, and subsequently subjected to a deductive thematic analysis methodology as described by Braun and Clarke (2006).

Results

Responses obtained suggest that the advent of *the COVID-19 pandemic* and the consequent implementation of new hygiene protocols in schools had a *limited impact on* the planned *teaching contents*. The teachers noted a substantial influence of new queries highlighted by students as well as demands from general protocols implemented at schools, such as allowing social distance, limitation of number of students in classrooms and hygiene procedures such as hand-washing. However, none of the interviewees explicitly reported any adjustments or additions to the biology curriculum content or teaching practices following the COVID-19 experiences. Hence, the implementation of interactional CL at schools generally did not translate into changes in tutoring regarding functional and critical aspects of CL.

Among the various themes encompassed within the CL framework, teachers ranked *hygiene* as their foremost teaching priority. Notably, three-quarters of middle school teachers emphasized this perspective when asked to allocate their classroom time across the six thematic areas.

When discussing *contagions*, including pathogenic bacteria and viruses, the predominant mode of instruction was *interactive* and was often prompted by student queries. Conversations pertaining to bacteria and viruses typically arose during activities such as cooking or discussions concerning hand hygiene.

A significant proportion of the participants acknowledged the significance of *transmission routes* in the context of health education; however, it was infrequently, if ever, integrated into their predetermined instructional content. When transmission routes were introduced into the teaching, this aspect predominantly occurred within the context of the COVID-19 pandemic. Typically, such discussions materialized in interactive dialogues, often centering around topics like isolation measures and related precautions.

A considerable number of educators engaged the topic of pupil *vaccinations* by interactive methods; however, none openly incorporated structured teaching contents related to vaccines into their curriculum. Contrarily, discussions concerning vaccines predominantly emerged in response to queries introduced by students. Some teachers perceived this subject as challenging to teach, largely due to its sensitive nature and the presence of parents who held anti-vaccine viewpoints.

Instructions concerning *antibiotics* primarily assumed a historical perspective or centered on discussions regarding the appropriate circumstances for antibiotic utilization.

Conclusions

When applying the CL framework, in the aftermath of the COVID-19 this study pandemic discerned that Swedish middle school teachers predominantly employed interactive health literacy in their teaching, whereas functional and critical health literacy elements frequently were lacking in their instructions on infectious diseases.

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Teaching experimentation / lab methods

Implementation strategies and barriers of biotechnology experiments into schools

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Theoretical background or rationale
Students struggle to differentiate between current and potential biotechnology applications, highlighting a gap between real-world science and what is taught in schools (Kidman, 2010). But teachers face challenges in teaching biotechnology, citing reasons like content complexity, time constraints, and lack of knowledge (Borgerding et al., 2013). Therefore, the TUM School of Social Sciences and Technology offers professional development (PD), that not only keeps teachers updated on the field's advancements but also equips them with the knowledge and resources needed for hands-on biotechnology experiments in their classrooms (Schöppner et al., 2022). It is designed to consider practical benefits and barriers known to implementation,
e.g. the duration of teacher involvement (Sims & Fletcher-Wood, 2021). Teachers can choose from various contexts tailored to the Bavarian school curriculum (ISB, 2015). These efforts align with models built on the process-product paradigm, such as the five levels of effective PD proposed by Lipowsky (2021): (1) teacher satisfaction, (2) changes in teacher knowledge, (3) improved teaching quality, (4) enhanced student outcomes, and (5) school development. However, interactions and mechanisms of action between these levels remain a major research desideratum (Davis et al., 2017).

Key objectives:
This study aims at insights into the implementation of biotechnology experiments into schools. Thereby, we focus on two research questions:

- On what aspects do teachers base their decision for or against implementing biotechnology experiments?
- How do teachers implement the biotechnology experiments into school?

Research design and methodology:
At the time of the survey, 289 teachers from 98 secondary schools have participated in the teacher training. We followed theoretical sampling and interviewed 39 teachers, 20 implemented the content at their school. The duration of the interviews took M=20 min (SD=10). We analyzed the transcripts in five steps: (**I**) Summarizing individual cases (Kuckartz et al., 2008). (**II**) Typification of decision making and implementation according to Mayring (2015). (**III**) Coding and inter-coding (30% of the material, κ = 0.89). The used deductive category system is based on existing research insights (e.g. Böhmer et al., 2017). The seven main categories with sub-categories given in parenthesis are: teacher training (5), personal characteristics (5), school organization (6), system features, innovation (4), cooperation (5), dissimilation (3). (**IV**) Analyzing overlaps both within and between categories and follow up
(**V**) inductive coding of the categories with the highest differences.

Findings:
In this paper, we present an overview of the most distinguishing categories between implementers and non-implementers. The individual perception of success factors plays a pivotal role. For example, the distance for equipment pickup is considered unbearable (30 minutes, non-implementer) to assessable (90 minutes, implementer). This leads to different argumentation outcomes while using the same arguments. Common influential factors center on the national curriculum, time constraints, and the classes taught. Cooperation and implementation strategy often undergo re-evaluation after implementing, which can lead to contrasting outcomes. As a result, an argument structure based on objective success factors can yield vastly different conclusions due to individual or collective perceptions.
In response to the second research question, we identified four different approaches to how teachers implement biotechnology experiments: (1) integration into regular classes, (2) inclusion in blocked school sessions (morning or afternoon), (3) incorporation within projects, and (4) incorporation into school-specific special subjects. Within three flowcharts we illustrate the primary findings, particularly the variations in decision sequences related to training participation (1), school organization (2), and actual implementation (3). Some schools even integrated the PD practical phase as a fixed part of their curriculum.

Conclusions:

Our study highlights the factors influencing the decision to incorporate biotechnology experiments into lessons. The results indicate that the teacher training modules are highly adaptable to individual school needs, aligning with prior research (e.g. Böhmer et al., 2017).. While Lipowsky's model has been previously evaluated on a level-by-level basis (e.g. Grünkorn et al., 2019), interactions between levels are rarely considered in conjunction with intervention measures. Furthermore, personal perceptions of factors across different levels are neglected. This interview study sheds light on decision-making regarding implementation. Notably, the assessment and prioritization of factors by individual teachers are critical determinants of actual implementation. Subsequent studies should shift their focus from identifying success factors to how these factors are prioritized.

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Comparing students' goal orientation when experimenting at an out-of- school science laboratory and at school

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Theoretical background or rationale

Student motivation has been decreasing during school time (Scherrer & Preckel, 2019). In Germany, a negative development of school-related learning and achievement motivation was found (Spinath et al., 2016). In higher grades, students' motivation to expand their own competencies (mastery goal orientation) is lower, while their motivation to demonstrate competencies (approach goal orientation) remains consistently high when comparing grades 4 to 12 (Spinath et al., 2016). Furthermore, as the grade level increases, so does the motivation to hide deficits (avoidance goal orientation; Spinath et al., 2016). These results raise concerns since a mastery goal orientation (MGO) can have a positive effect on various desirable educational outcomes whereas an avoidance performance goal orientation (avoidance-PGO) impacts those outcomes negatively (Payne et al., 2007; Spinath et al., 2016; Van Yperen et al., 2014). Additionally, motivating students is an important goal of (biology) education that does not seem to be achieved (Braund & Reiss, 2008).

Out-of-school learning might help achieve this goal by complementing traditional formal learning in school (Braund & Reiss, 2008; Scharfenberg et al., 2019). For instance, at out-of- school science laboratories, students can engage cooperatively in hands-on experiments under expert supervision using cost-prohibitive scientific laboratory equipment that is not normally available at schools. These characteristics of the learning environment could have positive effects on the adoption of MGO and the decrease of PGOs (see Meece et al., 2006).

Furthermore, in schools, students' performance is formally assessed based on normative criteria and social comparisons (Eshach, 2007) that could support the adoption of PGOs (Meece et al., 2006). Previous studies have found positive effects of visiting out-of-school science laboratories on student motivation, for instance, on their situational interest (for an overview see Scharfenberg et al., 2019). However, according to our current state of knowledge, the influence of a visit to these laboratories on students' state goal orientation (see Payne et al., 2007) has not yet been investigated.

Key objectives:

This research gap was addressed in the present study. We investigated whether students' state MGO as well as their approach- and avoidance-PGO differ when experimenting at an out-of- school science laboratory or experimenting at school.

Research design and methodology:

The sample comprised 358 students (M_{age}=16.43 years, SD_{age}=0.77 years, 58% female, grade 10 and 11) who were taught in enzymology at an out-of-school science laboratory (*n*=186) and at school (*n*=171). We used a quasi-experimental design. In the pretest, we assessed students' trait goal orientation in their prior biology classes (Midgley et al., 2000; 12 items, α=.79-.87) to test whether the treatment groups were comparable in terms of their prior motivation. Afterwards, the students performed the same three experiments (structured by worksheets) in group work under the supervision of the same preservice teacher in both treatments. In the out-of-school science laboratory, the students used laboratory equipment (e.g., micropipettes), and two groups were supervised by one preservice teacher. In the school treatment, the students used equipment that is normally available at schools (e.g., disposable pipettes). Here, the whole class was supervised by one preservice teacher. In the posttest, we asked the students for their state goal orientation (Midgley et al., 2000; 12 items, α=.68-.86). To compare students' prior motivation before and their motivational outcomes when experimenting, we used multi- and univariate analyses of (co-)variance.

Findings:
In pretest, no differences were found in students' trait goal orientation between the treatments (MANOVA: $F(3,354)=1.96$, $p=.119$). Regarding the state goal orientation in posttest, MANCOVA revealed significant differences between the treatments ($F(3,345)=7.54$, $p<.001$, $\eta_p^2=.06$). In the univariate comparison (ANCOVA), no differences were found in state MGO ($M_{difference}=0.07$; $F(1,355)=1.11$, $p=.291$), but the students at school had higher state approach- ($M_{difference}=0.47$; $F(1,348)=22.59$, $p<.001$, $\eta_p^2=.06$) and avoidance-PGOs ($M_{difference}=0.35$; $F(1,348)=17.82$, $p<.001$, $\eta_p^2=.05$) than the students at the out-of-school science laboratory.

Conclusions:
Our results support the assumption that out-of-school science laboratories provide an added value for learning. Although experimentation at the out-of-school science laboratory did not outperform experimentation at school in terms of students' state MGO, it was found to have a mitigating effect on students' avoidance-PGO, which tends to be less beneficial for learning (see Van Yperen et al., 2014). This is of particular importance since biology lessons deal with socially relevant topics such as biodiversity and climate change that students should also deal with beyond school (see Scharfenberg et al., 2019). Thus, formal biology learning should be complemented by visits to out-of-school science laboratories.

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Effectiveness and Challenges of Various Laboratory Methods in Biology Education

Vida Lang and Andrej Šorgo

Introduction

The field of education thrives on a variety of instructional methods and strategies that often incorporate, but do not rely exclusively on, technology. Educational discourse has evolved from a binary view of whether technology should be integrated into educational frameworks to a more nuanced exploration of its appropriate and effective implementation (Kirkwood and Price, 2014; Machkova and Bilek, 2013).
The intricate process of laboratory work involves careful planning, systematic fact-finding, rigorous data collection, methodical classification, sophisticated inference, and interpretive procedures. Often, the primary purpose of laboratory work is to immerse students in the essence of the scientific research process itself (Hodson, 1996). By allowing students to interact directly with tangible objects and operational processes, the laboratory environment proves to be a more engaging platform compared to passively absorbing information via didactic lectures. Educators agree that laboratory work not only deepens students' understanding of the subject matter, but also serves as a catalyst to stimulate and sustain students' interest in the subject (Johnstone & Al-Shuaili, 2001; Špernjak et al., 2009; Špernjak & Šorgo, 2018).
The efficacy and drawbacks of different laboratory methods have been discussed individually in research, with insights into their individual strengths and limitations (Brinson, 2015). However, there seems to be a lack of comprehensive studies that directly compare the strengths, weaknesses, opportunities, and threats (SWOT) of four different laboratory methods: the traditional laboratory, the computer-assisted laboratory, the virtual laboratory, and the smartphone-assisted laboratory. Therefore, the main objective of this study is to conduct a SWOT analysis that systematically evaluates and compares these four different laboratory approaches.

Methodology

Pre-servise biology, chemistry, and mathematics teachers enrolled in the Faulty of Science and Mathematics at the University of Maribor in Slovenia participated in the study. Participants took part in practical laboratory training as part of their subject curriculum.
Before starting the lab work, students asked to perform arguments for the introduction of individual methods of laboratory work. SWOT analyses was focusing on the four different lab methods: the traditional lab, the computer-assisted lab, the virtual lab, and the smartphone-assisted lab. Each student conducted an individual analysis and assessed the specific strengths, weaknesses, opportunities, and threats associated with each lab method. These analyses were based on their understanding of the methods, their previous experiences, and their perceptions. After the SWOT analyses were completed, the researchers collected and compiled the individual reports. The researchers then conducted a comprehensive analysis in which they reviewed and categorised the identified strengths, weaknesses, opportunities, and threats for each laboratory method for the entire cohort of participants.
This study serves as a foundation for exploring the comparative effectiveness and limitations of different laboratory methods in the biology classroom and provides a platform for further research and improvement of pedagogical practice.

Results

To analyze the results and document them in a scientific article, the answers could be categorized and summarized as follows:

Strenghts of the different laboratory methods:

1. Traditional laboratory:

Allows students to perform classical exercises using traditional equipment.
Promotes tangible experience in a real lab, hands-on experience, and student collaboration.

2. Computer-based laboratory: Quick

display of results.
Enables rapid data transfer to computers.
Efficiency, automatic data collection, and more reliable measurements.

3. Virtual laboratory:

Facilitates remote work and the ability to perform dangerous experiments that aren't feasible in a traditional lab.
Promotes the use of smartphones for educational and research purposes.

4. Smartphone-assisted laboratory:

Enables real-time monitoring of measurements, storage of results, and rapid, simplified viewing of events.
Handles mental and experimental processes that aren't feasible in a real lab.

Weaknesses of the different laboratory methods:

1. Traditional laboratory:

Requires consumables and risks equipment damage. Limited resources and time consuming.

2. Computer-based laboratpry:

Often struggles with safety and security issues.
Requires proper operation of sensors and other digital equipment.

3. Virtual laboratory:

Misuse can lead to unreliable data and misrepresentations.
Lack of interaction with real-world materials and risk of dependence on smart devices.

4. Smartphone-assisted laboratory:

Requires good knowledge and proper use of digital instrumentation.
Limits hands-on work can produce unpredictable results, and limits how experiments can be conducted.

Opportunities and hazards in various labs are more or less related to conducting lab exercises, using modern technology, and hands-on training. It's important to consider the opportunities and limitations of each type of laboratory.

Discussion

The results of the study provided information on the strengths and weaknesses of the various laboratory methods. The traditional laboratory was praised for its emphasis on tangible experience, hands-on training, and student collaboration. In contrast, computer-assisted labs were recognized for their rapid data display, automated data collection, and improved efficiency. Virtual and smartphone- assisted labs also offered special opportunities, such as working remotely, real-time measurements, and educational use of smartphones, illustrating their adaptability and accessibility.

Despite their strengths, each method has its drawbacks. Traditional labs face challenges related to resources, consumables, and potential damage to equipment. Computer-assisted labs face issues with security, sensor operation, and digital equipment. Virtual and smartphone-assisted labs face misuse issues that lead to unreliable data, dependence on smart devices, and limitations in practical applications.

The study underscores the importance of understanding the opportunities and challenges of different laboratory methods, especially with regard to cutting-edge technology. While virtual and smartphone-assisted labs offer innovation, they also pose risks related to overreliance on digital devices. The traditional lab, while reliable, is reaching the limits of resources and practicality.

These findings highlight the importance of selecting appropriate lab methods that fit the context and learning objectives. In addition, the study emphasizes that a variety of lab methods should be integrated into the classroom to ensure comprehensive learning experiences and to meet the diverse needs of prospective teachers.

The next important step is to consider how these laboratory methods can be combined or adapted to capitalize on their strengths and mitigate their weaknesses. For example, combining student collaboration in the traditional lab with automated data collection in the computer-assisted lab holds promise. Selecting an approach that is consistent with educational goals and available resources is critical. Using a mix of laboratory approaches can increase the effectiveness of instruction, enhance student engagement, and promote deeper understanding of scientific concepts.

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Using middle school students' challenges to teach the control-of-variables strategy for experimentation

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Theoretical background

Understanding scientific practices is fundamental for scientific literacy, a key goal of biology education (e.g., NRC, 2013). One core scientific practice is experimentation, including the "control-of-variables-strategy" (CVS; Chen and Klahr, 1999) which requires both procedural and logical knowledge. Despite its long-standing presence in science education, student challenges persist with the CVS (Kranz et al., 2022). Consequently, innovative teaching approaches are needed, such as using students' errors – derivations from the norm – as learning opportunities, e.g., in problem-solving-prior-to-instruction-settings (PS-I) (Zhang & Fiorella, 2023). Here, learners work on problem-solving-activities, followed by instructions and reflections on possible errors. Research highlights three key mechanisms for effective PS-I: activating prior knowledge, focusing on the to-be-learned strategies, and promoting error- awareness (Zhang & Fiorella, 2023). Other commonly mentioned, potential influences are affect, motivation, and cognitive load (e.g., Zhang & Fiorella, 2023), which leads to the assumption that not only students' own, but also others' (vicarious) errors could be learning opportunities.
Few studies explored PS-I for experimental skills (Chase & Klahr, 2017; Matlen & Klahr, 2013). PS-I did not outperform other forms of teaching, however, the studies did not incorporate prompted reflection on potential errors, which has been proven essential for PS-I to be effective (Zhang & Fiorella, 2023). Studies regarding vicarious errors are lacking, yet factors like potential differences in cognitive load, and the role of motivation and emotions hint at their potential.

Key objectives:

Based on prior research we investigated:

1. Do students gain higher CVS-skills by engaging with self-generated or vicarious errors, a combination of both, or by engaging only with correct solutions and instructions?
2. Is the postulated learning effect mediated by the students' cognitive load, their intrinsic motivation, their emotions after the error analysis or their error-awareness?

Research design and methodology:

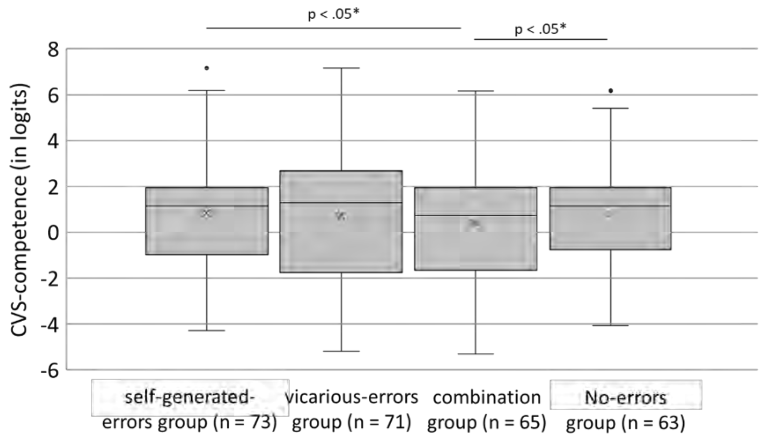
We conducted an experimental interventional study (pre-post-follow-up) with middle school students (n = 272, 40.1% w, 1,7% d., grade 7-8, M_{age} = 12.8, SD_{age} = 0.7), using a randomized 2x2-factorial design where the factors "self-generate-approach" and "vicarious-approach" were varied. This resulted in four conditions: a self-generated-errors-group (n = 73), a vicarious- errors-group (n = 71), a combination-group (n = 65) and a no-errors-group (n = 63).
The intervention followed the PS-I-approach. First, the self-generated-errors-group conducted experiments themselves. The vicarious-errors-group used prepared, erroneous experiments, and the combination-group worked with a mix of both. All three then received instructions and prompts to reflect on (possible) errors. The no-errors-group worked with correct experiments and got instructions on CVS.
We assessed students' CVS-competence (Schwichow et al., in prep.), emotions (Watson & Clark, 1988), cognitive load (Klepsch et al., 2017), motivation (Wilde et al., 2009) and error awareness.
To test if students' pretest-scores and group-assignment were statistically significant predictors of their learning outcomes, we used simple linear regression. Dummy coding (e.g., 0, 1) was used to compare the self-generated-errors, vicarious-errors, and no-errors-group to the combination-group. ANOVA and Tukey post-hoc analysis was used to determine group- differences for motivation, emotion, and cognitive load. We used individual structural equation models to test for possible mediations.

Findings:

The overall regression was statistically significant (R^2 = 0.5122, F(4, 265) = 69.56, *p* = <.001). Pretest-scores (□ = .754, *p* < .001) and group-assignment (self-generated-errors [□ = .658, *p* = .025] and no-errors [□ = .704, *p* = .021]) were significant predictors of posttest performance, in which they significantly outperformed the combination errors group (see figure 1).

Figure 1

CVS-posttest results (in logits). Higher numbers describe higher CVS-skills. Data show significant differences between the self-generated-errors-group and the combination-group and between the no-errors-group and the combination-group.



We found significant differences in negative emotions (F(1,3) = 4.468, *p* < 0.01) and extraneous cognitive load (F(1,3) = 3.640, *p* = 0.01). The self-generated-errors-group experienced more negative emotions than the vicarious errors-group (*p* = .029, .17, 95%-CI[.01, .32]) and the no- errors-group (*p* = .013, 95%-CI[.03, .35]). For extraneous cognitive load, the self-generated- errors-group experienced more extraneous load than the no-errors-group (*p* = .012, 95%-CI[.08, .84]). Yet, the structural equation models did not reveal any mediating effects for cognitive load, motivation, and emotions. Effects of learners' error-awareness are currently analyzed.

Conclusions:

Errors are valuable learning opportunities for CVS; but combining self-generated and vicarious errors does not offer expected benefits, potentially due to confusion about the learning method to be used. Surprisingly, more direct instructions without hands-on practice or error reflection led to a learning gain when the principles of CVS are addressed. While theoretical lessons should not substitute practical ones, this can be particularly beneficial when resources are limited.

Self-generating errors lead to higher extraneous cognitive load and more negative emotions, but these processes did not mediate the learning gain. Results will be discussed in detail at the ERIDOB 2024 and we hope to contribute to new ideas to fostering the understanding of scientific practices in the biology classroom.

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SYMPOSIUM

The role of biology education in preparing for a warming world

How preservice teachers deal with tensions in teaching climate change

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Theoretical background or rationale

At its core, climate change is the concept that human activities, mainly greenhouse gas emissions, are causing changes in the earth's climate, which in turn, has severe consequences for our way of life (IPCC, 2023). Climate change education is key in combating climate change (UNESCO, 2020). As an educational topic, climate change brings political, emotional, and ethical aspects to the biology classroom. This challenges traditional biology and science education teaching traditions and calls for teacher education to prepare pre-service teachers who are able to consider and embrace all aspects when they teach about climate change (Ojala, 2022; van Poeck et al., 2019). A recent study demonstrated how Swedish preservice science teachers beliefs about teaching climate change, leads to tensions (Author et. al., submitted, 2023). The three tensions revolve around; 1) dealing with values, 2) dealing with emotions, and 3) aligning the ends with the means. The third tension relates to achieving coherency among teaching strategies, content, and the purpose of teaching about climate change when preservice teachers reflect on it. While this study shed light on preservice teachers' beliefs about teaching climate change, it's crucial to explore their decision-making and reflecting when actually teaching it. In other words, how their didactical choices allow them to consider and deal with the tensions. This will be the focus of this study. The participants (N=12) in this study, are preservice teachers in the science studies subject participating in a biology course. The science studies curriculum is open for teaching about climate change, by embracing an interdisciplinary perspective on socio-scientific issues (National Agency for Education, 2012). Biology is a key scientific discipline incorporated into the science studies curriculum. The subject is mandatory for all upper secondary school programs in Sweden, with the exception of the science and technology program.

Research design and methodology:

The study employs an analysis of pre-service science studies teachers written assignments from a micro-teaching assignment in a climate change didactics course. The assignment consisted of four steps. First, to reflect upon and write how they want to teach about climate change. Second, to write a lesson plan for a teaching sequence with a time limit of 25 minutes. Third, to perform the teaching sequence where the other pre-service teachers acted as pupils. Finally, to write a discursive text, motivating and reflecting upon their didactical choices in relation to first three steps of the assignment. For this study, data consists of the written material from the assignment. The data was analyzed in four steps. First, familiarization with the data. Second, coding guided by five questions concerning: teaching sequence aim, content, teaching strategies, pupil characterization, and teacher role. Third, discussing the codes to form initial categories. Finally, defining categories for different teaching types used by the preservice teachers.

Findings:

The analysis revealed four categories of teaching that the participants employed.

Scientific concepts

Here, the aim is to provide pupils with understanding of scientific concepts. The content includes extreme weather, the greenhouse effect, the carbon cycle, and oceanic temperature change. Understanding scientific concepts enables pupils to make informed decisions, develop well founded values, participate in discussions, and handle their emotions. Isabella, one of the preservice teachers, emphasizes how the scientific concepts should be central in the following quote. "My ambition is to move the climate change issue from being a value-issue, and instead show that it is a facts-issue"

The pupils' life world

Here, the pupils' daily lives, habits and interests are central to the teaching. The aim is often to allow pupils to discuss and understand how things in their daily lives, such as clothes or mobile phones, contribute to climate change. The content in focus is often consumption. An additional aim is to influence pupils' behavior, such as their consumption choices. Linnea sets the aim of the teaching sequence as giving the "pupils an image of how and when the climate change issue can be seen in everyday life and how to work for sustainable development."

Society and climate change

Here, the content is climate change-related issues on a societal level. This is for example the UN's sustainable development goals, nation-wide policies, and greenhouse gas emissions from different sectors in society. The aim is to provide students with an understanding of this content, and develop their ability to discuss and position themselves. Lucas takes a critical view by showing the pupils how “the world’s largest carbon-emitters has a bias in the information they share”.

Creative vision
Here, the aim is to develop pupils’ creativity. The creativity is described to help pupils solve problems, and by envisioning solutions to the climate change issue give them a sense of hope. The content revolves around fictitious future scenarios. This category attempts to move away from fact-centered or normative teaching traditions, exemplified by Agnes who takes a stance regarding her role as a teacher in that “my role is therefore not to transfer knowledge or tell pupils how they should be or act”.

Conclusions:
The preliminary findings reveal four types of teaching that the preservice teachers choose to employ. These types vary in how they allow the preservice teachers to deal with tensions in teaching climate change. While the preservice teachers in the scientific concepts category reason about values and emotions in their reflections, it is unclear how their teaching approach allow them to deal with the tensions. In the pupils life world category, they manage to align the ends with the means. However, there are normative tendencies which conflicts with the notion of being neutral in the role as a teacher in the tensions of values. This also applies for the society and climate change category. Here however, the tension of emotions can be dealt with through the deliberative discussions between teacher and pupil. How the creativity and vision category allow for dealing with tensions, relies on how the fictitious scenarios are designed which the preservice teachers show awareness of. The findings demonstrates where teacher education should support preservice teachers.

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Primary school teachers' planning and teaching of an authentic sustainability dilemma – a case study

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Out-of-school activities on climate-related risks – the case of riskville

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Theoretical background:
Non-formal out-of-school activities, such as field trips or visits to science centres, may be used to provide pupils with first-hand experience with environments or phenomena they previously did not have (Eshach, 2007). However, without a clear understanding of the purpose of out-of-school activities, there is a risk that pupils regard them as a fun day out with limited opportunities for learning (Tal, 2012). The present study aims to contribute to students' development of climate change risk perception (Aksit et al., 2017), with a particular focus on the increased risk of flooding in the region where students live.

Key objectives:
The key objectives of the study are to provide examples of students' participation in an out-of-school activity on the theme of climate-related risk, and show how it contributes to students' development of competence with regard to natural hazards and disaster risk reduction (Oyao et al., 2015).

Research design and methodology:
150 grade 8 and 9 students participated during a day each in out-of-school activities on the theme of climate-related risks with a focus on flooding. The day was organized as part of a participatory action research project (Eilks, 2018) on climate education, in collaboration between science education researchers and teachers at three lower- secondary schools.

During the first activity, Floodwalk, students walked along the riverside of their home city, and were made aware of locations that are particularly vulnerable to flooding, such as buildings close to the water and viaducts. Next, students participated in stations at the university. Students were given the task by the Climate Students Association to make posters that convey a message that relates to climate change in order to influence others to take action, and played Floodville, based on a topographical model of the city, where they negotiate and decide what parts of the city to protect when the water level of the river rises.

Students also played Riskville, in which a model of a city is built with wooden blocks on a felt carpet (see Figure 1), the activity in particular focus during this research study. Students working in small groups were first asked to make the city an attractive place to live in and were then confronted with climate-related events, such as flooding due to torrential rain. Students were instructed to show on the carpet the consequences of such events, and discuss how they could be addressed or prevented.

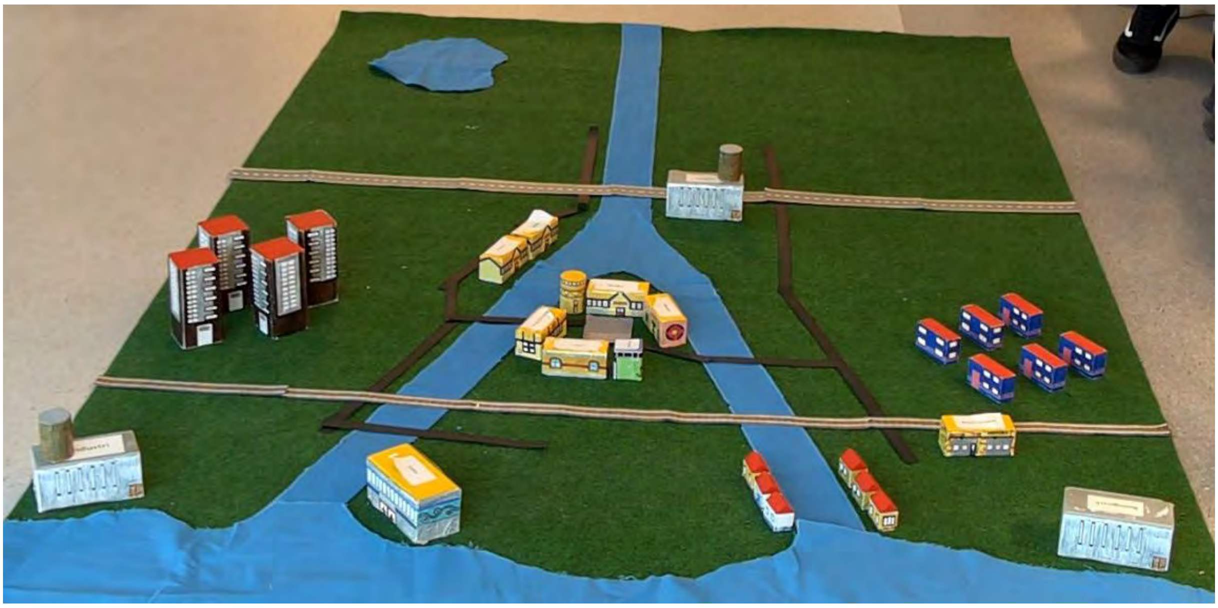

Figure 1. Initial configuration of Riskville. A city is located where a river enters a large lake.

Five of 13 groups of students were video recorded as they participated in Riskville, and we adopted a narrative approach to video analysis (Derry et al., 2010). The competence-based science learning framework (Oyao et al., 2015), emphasising the dimensions of content knowledge, cross-functional skills, dispositions, connectedness, and behavioural actions, was used to analyse the students' engagement with the activity.

Findings:
Video analysis of Riskville shows that most of the students were engaged in building an attractive city, assuming a perspective of their age group, such as building bicycle paths between residential areas and recreational activities. They could identify locations and buildings that are vulnerable to flooding, such as areas close to a river or viaducts, but had difficulties finding ways to avoid flooding.

While most of the students expressed a positive attitude toward playing the game and contributing to an attractive and resilient city (see Figure 2, left), some of them did not engage with the exercises or disrupted the game by adding less attractive features to the city (see Figure 2, right). Group sizes and the age of the participating students were identified as factors behind the students' level of engagement with the activity.

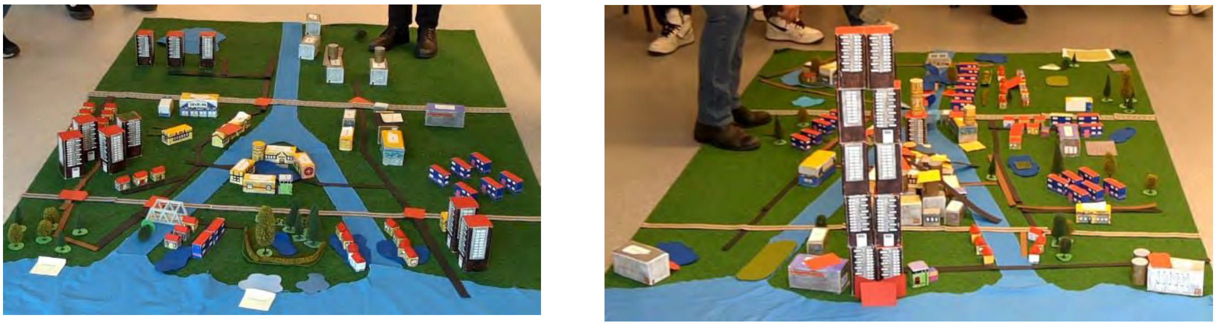

Figure 2. Screen shots of Riskville. Students have identified locations and buildings that are vulnerable to flooding with blue and red patches (left). Students have built a skyscraper and industries in the town centre (right).

Conclusions:
The out-of-school activities on climate-related risk give students opportunities to develop their content knowledge related to flooding, in terms of their scientific knowledge, and understanding of the impact of flooding and risk reduction (Oyao et al., 2015). In particular, the activities provided a societal focus on adaptations that goes beyond the typical focus on mitigation, e.g. reduction of students' individual carbon footprint, in climate education (Bofferding & Kloser, 2015). The results of the video analysis of Riskville show that students concretize their understanding of local climate- related risks and develop their decision-making skills through collaboration and negotiation. Small group sizes were found to stimulate students' engagement with the activity.

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“I want you to panic” – Risk perception as a driver for young people’s climate action

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Theoretical background

Enabling students to address socioscientific issues (i.e., science-related problems of major societal relevance) has been identified as a central goal of modern science education (Zeidler, 2014). This includes equipping students with the knowledge, skills and attitudes to act responsibly in the face of pressing issues such as the rapid loss of global and local biodiversity, a topic often discussed in biology classes in the context of climate change (see DeBoer, 2000; Yli-Panula et al., 2018). One example of taking responsible action in the context of climate change is students’ participation in the *Fridays-for-Future* movement, a global youth movement that has already mobilised several million people through demonstrations for stricter climate protection (Fisher & Nasrin, 2021). Up to date, however, there has been a lack of research examining the different factors that drive young people regarding their climate action and there is only scattered insight which role biology education can play in this regard (see Bhattacharya et al., 2021).

In psychological research, risk perception has already been found to be a valuable driver for students’ engagement in climate action (e.g., Brügger et al., 2020). According to van der Linden’s (2015) climate change risk perception model (CCRPM), the different dimensions of risk perception comprise: cognitive factors (e.g., knowledge about the causes of climate change), experiential processing (e.g., personally experiencing consequences of climate change), socio-cultural influences (e.g., endorsement of different value orientations). Yet, the question of how the various dimensions of risk perception are found among young people who engage in climate action remains open.

Key objective

Following up on this research gap, the proposed research investigates what aspects of risk perception are expressed by individuals who actively participate in youth-led climate action. Using this approach provides a closer look at what motivates people to engage in climate action and opens a discussion about the potential role of science, and in particular, biology education. Thus, the overarching research question reads: What dimensions of the CCRPM by van der Linden (2015) do young people refer to when reporting their involvement in climate movements?

Research design and methodology

To approach this research question, fifteen semi-structured interviews were conducted with young adults (18-29 years) in Germany who are actively involved in the *Fridays- for-Future* climate movement. The interviews were conducted predominantly in person (N = 11) (digitally if requested; N = 4) and lasted about 60 minutes. After the interviews were transcribed, data was analysed using the method of qualitative content analysis according to Kuckartz (2014). In developing the categories of analysis, we used both a deductive approach based on the CCRPM by van der Linden (2015) and an indictive approach to refine existing categories and add new ones as needed.

Findings

The preliminary results of the interview analysis show an ambivalent picture regarding the risk perception of the participants. At a descriptive level, all three dimensions of the CCRPM are covered in the majority of the interviews, with cognitive factors being particularly evident (e.g., a variety of possible responses to climate change, such as reducing emission in mobility issues) and socio-cultural influences coming second (e.g., advocacy of altruistic values, especially with regard to the lack of climate justice). In addition, participants cited perceived risk as a reason and justification for their actions. On the other hand, risk perception was sometimes also perceived as an obstacle to climate action, as it was closely linked to feelings of being overwhelmed and powerless.

Conclusion

Given the many negative impacts of climate change on life on Earth, this paper explores a pressing and timely context. To respond as responsible citizens to the challenges associated with climate change, we need to better understand how to help young people engage in climate action. Preliminary results from our study confirm that, in addition to cognitive factors, young people's perceptions of risk may be a key variable in explaining their motivation to engage in climate action. For biology education, the findings of this study suggest that it may not be sufficient to focus solely on climate-related knowledge and skills, as is commonly done (see Kranz et al., 2022). Instead, learning about climate change should also target socio-emotional factors for example by enabling discussions about possible consequences at the global and local levels. However, focusing exclusively on risks could also lead to increased defensiveness and displacement among students (Doherty & Clayton, 2011). Further research is therefore needed to examine how risk perception should be (carefully) addressed in the biology classrooms so that it is perceived as a driver rather than a barrier to students' climate action.

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Posters session 2

Biological, Racialized and Pleasurable Bodies - Carl von Linné (Linnaeus) and sexuality education in the 1700s.

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The history of sexuality education can be told in various ways. From the 20th century and onwards, it has become a strategy for social ends to increase public health, sexual awareness, sexual rights and gender equality (UNESCO, 2018). In this narrative, education has become pivotal in shaping responsible sexual behavior and relationships among adolescents. The role of sexuality education have often fallen upon biology teachers as reproduction is one of the core component in the subject (Reiss, 2018). Through sexuality education, students are able to engage with controversial topics of sexuality as well as explore "what is good and what is right" (Reiss, 2022). Placed in the realm of education, sexual knowledge disseminates stories about the body as a biological, social, and pleasurable entity but also work as a normative force as it provides particular understandings of sexuality in specific settings (Fingalsson & Junkala, 2023).

In Sweden, where sexuality education has been a mandatory part of schooling since 1955, one of the earliest accounts of it in formal education is provided by no less than the famous naturalist and botanist Carl von Linné (Linnaeus). In his lecture, *Collegium Medicum* - *Om sättet att tillhopa gå* [*Regarding the way to come together*], Linnaeus provides a lively account on human sexuality. While sexual reproduction is necessary for all animals, Linnaeus distingued the human species from other anthromoporfa species by the Greek motto *Nosce te ipsum* [*know thyself*]. Thereafter, he divided humankind into four racialized sub-groups. Over the course of 23 years and ten editions, Linneaus work and develop his classifications of man in *Systema Naturae* (1735-1758) (Linnaeus, 2023). According to Linnaeus, the four sub- groups were the (1) copper-coloured *Native American*, regulated by customs, (2) the fair, sanguine, brawny *European*, governed by laws, (3) the sooty, melancholy, ridgid *Asians* and (4) the black, phlegmatic, relaxed *African*, governed by caprice (see Eze, 1997, p. 13; Linnaeus, 2023). Linnaeus classification is brief, yet it provides us with one of the earliest accounts of biologizing humans as "races" (Hoquet, 2014). In an attempt to engage with Linnaeus lecture on human sexuality, reproduction and race this presentation aims to address the normative force of sexuality education by understand *if* and *how* Linnaeus's lecture relates to his crafting of human differences. Asking, *how* and *what* Linnaeus lecture on sexuality and human reproduction can inform about the "thyself" that the homo sapiens ought themselves to "know"? Reading Linnaeus work in paralell with his lecture is key, for while his classifications in *Systema Naturae* are restrained, his lecture on sex offers vivacious explanations of the "natural" sexual constitution of the homo sapiens.

However, this reading requires guidance. When working with a concept of race, Staffan Müller-Wille (2014) presents a dilemma familiar to most; for how are we to approach an object (race) that is built upon a false idea. According to Müller-Wille, "[i]f one accepts the conclusion that race is a concept that builds on fallacious ideas, one faces the difficulty of explaining how a mere delusion or misperception could gain such enormous power over the minds and bodies of many" (2014, p. 599). This presents a serious, and potentially devastating problem as it can undermine the social reality of suffering and dismiss the mechanisms that supported this endeavor to be merely a glitch in the history of mankind. The response to this could be to turn to the empirical or rational substance that a concept of "race" might have had in the past. However, then one could be "faced with the danger of re-legitimating racialism - the idea that race reflects some fundamental aspect of reality - in retrospect" (Müller-Wille, 2014, p. 599). Müller-Wille (2014) proposes that the solution to the dilemma is neither to reduce "race" to be a representation nor as a mirror of an object, but to approach "race" as a *mental tool*. Unlike representations, "[t]ools do not need to bear any kind of similarity with the object they are supposed to affect" (Müller-Wille, 2014, p. 600). This is an important distinction for by reading Linnaeus work as *mental tool* for ordering knowledge, his accounts can be read as *functional objects* - anchoring points from which values, judgements, and consequences follows. By classyfying the human constitution, Linneaus placed the human in the natural order but also naturalised difference on the basis of colour, geography and customs (Müller- Wille, 2014). Unlike other contemporary naturalists, Linneaus schema froze differences in man while others, such as G.-L. Leclerc de Buffon (1707–1788) argued that the diversity of man is infinitive (Hoquet, 2014). This approach in biologizing the human body is also noticable in his lectures on human sexuality.

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Controversy mapping to address the socially acute question of an urbanisation project over an aquifer

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Theoretical background or rationale

In today's society, there are significant social controversies that can be brought into the classroom through different approaches, such as called *socially acute questions* (QSV, from French) (Legardez, 2006; Simonneaux, 2014). Legardez (2006) defines these QSV as questions that are alive for society because they are socially and in the media addressed and are present in debates and controversies in scientific, professional, political and cultural spheres. These QSV can be addressed in science education, considering the students' engagement with the question. According to Simonneaux (2014), such engagement ranges from the "cold end" to the "hot end". At the "hot end", it is a matter of moving students and teachers towards activist approaches based on scientific and technological enquiry (Reis, 2014).

Currently, there are important controversies related to the model of water management and consumption, and it is crucial to identify the knots or critical points to be untangled (J. Simonneaux et al., 2017). An example is found in the municipality of Coín, southern Spain, where there is a karst aquifer that collects rainfall and drains into several springs that have traditionally irrigated its orchards, constituting a core of the municipality's economy. In the summer of 2023, an urbanisation macro-project was presented which plans to build a tourist, sports and leisure complex, whose dimensions threaten to definitively exhaust the water of the municipality, in addition to causing ecological impacts on a nearby National Park (enandaluz.es, 2023). The community has rallied against this project, forming organizations amid strong pressure from economic and business sectors supporting it. This has generated a significant social controversy, transforming the approval of this plan into a QSV (González, 2023).

The cartography of controversy is an approach to address QSV that can be used for both socioepistemological research (Nédélec, 2018) and educational approaches (AUTHORS, 2023; J. Simonneaux, 2014). One of its essential tools is the map of controversies, allowing the visualization of complex social phenomena and rooted in actor-network theory (Latour, 2005), where there is the concept of "*actant*" as an entity, human or not, that has an impact on QSV.

Key objectives:

This paper presents the Cartography of controversy on the QSV of an urban development project on an aquifer in the municipality of Coín (Málaga, Spain) as part of the socioepistemological enquiry. To this end, the controversy map is presented, which allows us to visualise the complexity of QSV as a first step and socioepistemological study to use it in education through activist interventions subsequently.

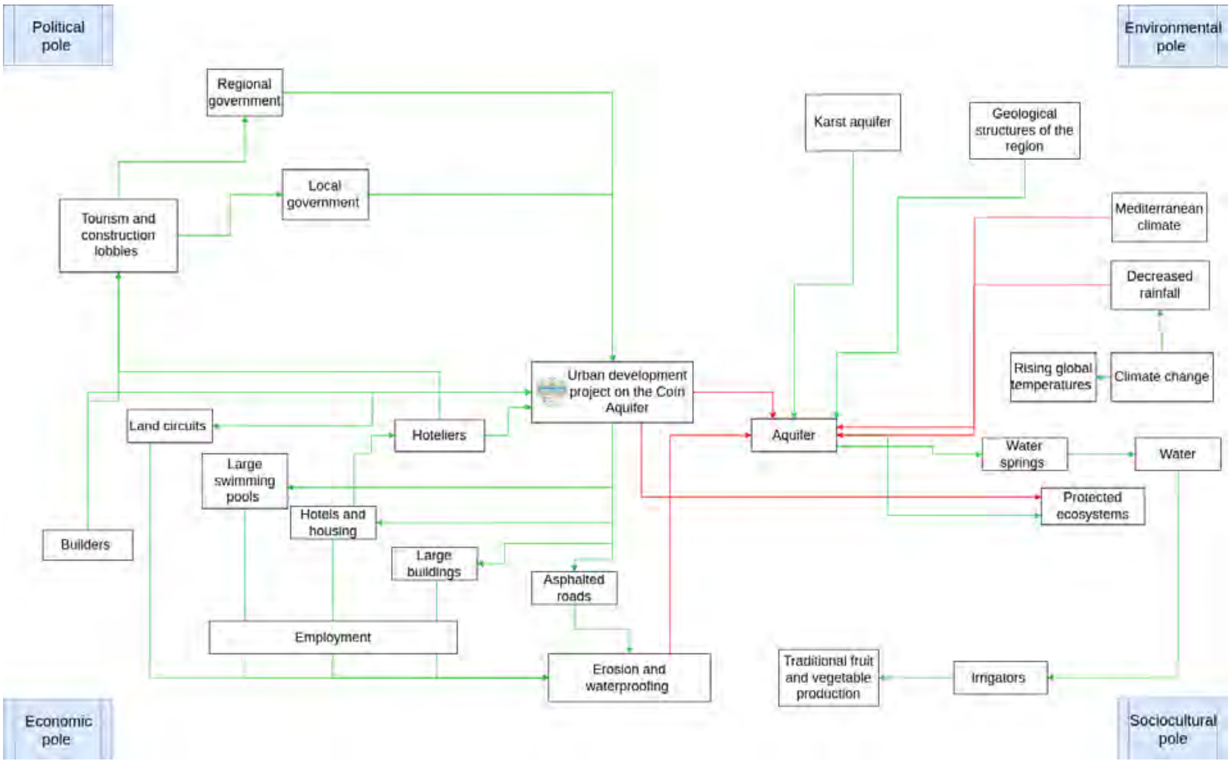
Research design and methodology:

Based on the ideas of Latour (2005) and Nédélec (2018), the method for the elaboration of the controversy mapping included the following phases:

1. Choice of the QSV
2. Identification of actants and poles involved in the QSV
3. Location of the actants in each pole
4. Identification of the possible relations between actants

Findings:
As a preliminary result of the socioepistemological research, an initial controversy map has been constructed and is presented in Figure 1.

Figure 1.
Map of controversies on the QSV of the urbanisation project over the Coín aquifer.



The actants involved in this cartography of controversy have been grouped around four poles: environmental, sociocultural, political and economic. Actants whose activity affects more than one pole have been placed in intermediate zones. The relationships have been represented with green arrows if the action of the actant in question favours the activity of the one on which the arrow falls, and with red arrows when it opposes such activity.

Conclusions:

The controversy mapping carried out by the experts gives an overview of QSV (Venturini, 2008) and helps to understand and identify the actants, relationships and interests involved (Latour, 2005). The issue chosen allows many aspects of science and almost all current environmental, ethical, economic and political issues to be addressed in an integrated way. The map can be used to express initial ideas, as a forum for debate and integration, and as a starting point for developing activist proposals. For the activist proposals, the map would allow structuring and guiding the raising of concrete issues within QSV and initiating processes of enquiry that would end with the proposal of solutions and the development of sociopolitical interventions (Reis, 2014).

Acknowledgement:
This work was supported by the R&D project…

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Impact of public service announcements (PSA) on reactance to socio-scientific issues

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Biotechnology experiments in the classroom – effectiveness of practical units on learning output

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Theoretical background or rationale

Practical laboratory lessons influence the learning success of students (Barzel et al., 2012). Practical lessons are relevant for causal and logical thinking. Kerschensteiner (1952) defined practice as essential for complete learning. The anglo-american world demonstrated already the high value of inquiry learning and laboratory work on student learning (Edelson et al., 1999; Sunal et al., 2008). Classroom exercises teach both practical skills and approaches for problem-solving, e.g. experiments (Bewersdorff & Baur, 2019). Biotechnology, in particular, is a broad field used in many professions (Schöppner et al., 2022). In order to increase the learning output of students, teachers should improve their skills and, thus, the quality of their teaching, especially in such relevant areas, through teacher training (Festel et al., 2004). The quality of teaching has a direct impact on the learning output of the students (Lipowsky & Rezejak, 2012). Therefore, the Technical University of Munich offers a biotechnological teacher training, which minimizes implementation hurdles by enabling teachers to borrow the necessary equipment and reagents free of charge (Schöppner et al., 2022).

Key objectives:

This study evaluates to what extent selected design features of instructional quality influence students' learning output. The aim is to contrast the effect of practical and theoretical instructions regarding biotechnology on students' methodological skills.

Research design and methodology:

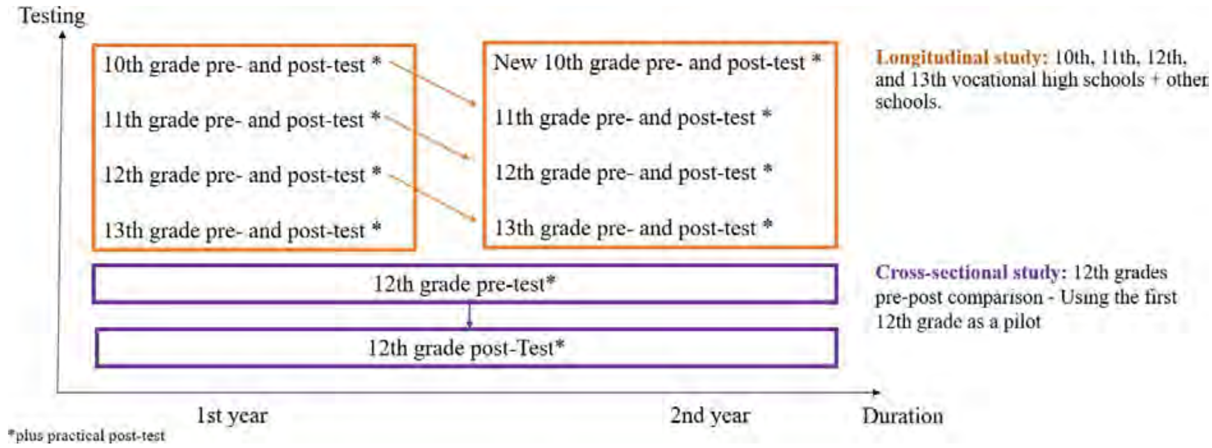
Students in the subject biology of grammar schools, vocational schools and vocational high schools are the target group (planned N= 300 experimental group; 300 control group).

The experimental groups (eg) are taught by teachers who practically implement biotechnology in their lessons; the control groups(cg) by teachers who focus on theoretical input. Due to ethical considerations all students remain in their classes which limits the comparability of eg and cg. We perform a quantitative knowledge test in a pre-post design in the biology classes on genetics. After the pre-test, the experimental group participates in the videotaped practical unit. Additionally, in both groups (planned N = 120; cg and eg) methodological knowledge, e.g., performing a PCR or evaluating agarose gel electrophoresis plates, is queried in a practical test and videotaped after the quantitative knowledge post-test. Therefore, six students from each class are selected randomly. They are divided into three groups according to the teacher's assessment of their educational performance: very good biological performance, mediocre biological performance, insufficient biological performance.

Both the post-test and the practical part take place in the follow up biology session of the respective classes and thus offer comparability.

A pilot study of the knowledge test and the practical post-test will take place in autumn 2023 with students from the Technical University of Munich. It provides information about test suitability and quality. An additional pilot study at schools will start in summer 2024 and verify the quality of the measurement instruments in the final setting. Both the pilot and main study at Bavarian schools requires approval by the Ministry of Education.

The complete process of the planned study can be seen in Fig. 1. For the longitudinal study four grades are surveyed in two consecutive years (2024, 2025). Thereby, the survey of each study year represents a cross-sectional study that can be analyzed both in total and distinguished in school types.



Expected results:
It is expected that the testing of the measurement tools with the students will give a mixed result compared to the testing in school. However, it is expected that individual knowledge acquisition will be measurable. Furthermore, students will learn practical skills such as handling reagents or equipment. These outcomes will be targeted in the poster presentation.

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Changes in students' conceptions of evolution in lower and upper secondary school

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Conceptual test focused on nervous system

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Theoretical background or rationale

Taking into account the dynamic development in the field of neuroscience, in 2021 a conceptual framework for high school level neurobiology (Kvello & Gericke, 2021) was proposed as a starting point for educational purposes. We take a further step and construct a conceptual test covering selected neurobiology concepts.

Key objectives:

Conceptual test, nervous system, high school, neuroscience

Research design and methodology:

Building on the conceptual framework proposed by Kvello & Gericke (2021) (specifically, 11 of its 26 concepts), we have developed a conceptual test. The validated test aims to measure and assess the level of understanding of neurobiological processes and principles, thus contributing to the evaluation of the teaching process. The test items focus on concepts 4 -14 with medium level of complexity. The conceptual test comprises single-best-answer questions (Štuka & Vejražka, 2021). The pilot testing and subsequent validation involved 155 respondents from Prague high schools (131 students) and secondary medical schools (24 students). All students were taught about the nervous system at school. Approximately half of the students learned about the nervous system for 4 months before the testing and revised the topic before the test. The second half took the test without a revision two or three months after finishing the topic nervous system at school. To identify items suitable for the second version of the test, we used methods of Classical Test Theory and Item Response Theory for the analysis as in Kalinowski et al. (2016) and McFarland et al. (2017) using the ShinyItemAnalysis application (Martinková, 2017) and the feedback from respondents on the items content and phrasing. The second version of the test is being developed and will be prepared after consulting with experts in the field. This version will be administered to and tested on a sample of approximately 400 students from Czech high schools and secondary medical schools.

Findings:

Out of the initial 43 test items in the first version, 6 were deleted (due to duplication and insufficient discrimination and other parameters), and 13 were modified for the second version to ensure that all selected concepts were adequately covered.

Acknowledgement:

This work was supported by the Charles University project GAUK: Neuroscience literacy and how are we doing? Development and validation of a conceptual test focused on the nervous system (project number 210623).

Conclusions:

This conceptual test aims at providing teachers and students with the opportunity to verify whether they understand selected neurobiological concepts correctly. The test can be a significant tool for understanding and knowledge of nervous system assessment. Teachers can use the test to monitor the progress of their students and identify areas that require further improvement. The test will be available in English and Czech languages.

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Implementing a precursor model for the teaching-learning of evolution in kindergarten. A teaching intervention to conquer population thinking

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Students' knowledge of ocean acidification and its impact on marine organisms

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Theoretical background

The world ocean becomes more acidic due to the fact that it absorbs most of the increased anthropogenic carbon dioxide (CO2) in the atmosphere, leading to ocean acidification (Doney et al. 2009), which is a major threat for marine species and ecosystems, since it affects the calcareous skeleton building capacity of organisms such as molluscs, echinoderms, or corals and the fall of phytoplankton. Considering that citizens through their everyday lives contribute to the increased CO2 emissions, the scientific community considers it a priority to establish public awareness and understanding of ocean acidification (Andersson & Mackenzie, 2011), so as citizens and students, who are regarded as future decision-makers, can make informed lifestyle choices to minimize this impact. However, the dearth of research concerning either public's or students' knowledge of ocean acidification or the carbon cycle has articulated participants' low awareness (e.g. Hartley et al., 2011; Spence et al., 2018).

According to Ocean Literacy Framework (National Marine Educators Association, 2010; National Oceanic and Atmospheric Administration 2013), ocean acidification could be taught at 11-12 year-old primary students. Generally, existing teaching approaches concerning ocean acidification are disconnected from the carbon cycle, although it is a complex environmental problem directly associated with the increased CO2 emissions in the atmosphere. Moreover, to the best of our knowledge, there are no relevant studies concerning ocean acidification teaching to primary students either disconnected from the carbon cycle or not.

Key objectives

The aim of the present study is to estimate 11-12-year-old students' knowledge of the carbon cycle and ocean acidification before and after a teaching intervention. The present study will provide important information whether the introduction of ocean acidification in a carbon cycle context can help young learners understand the human impact on this complex environmental problem. This would be the first crucial step to help them realize how important everyday individual action is for the mitigation of such environmental problems.

Research design and methodology

The study was conducted with a convenient sample of eighty-five 11 to 12 years-old students from 5 classes in two public primary schools located in a coastal provincial town, in Greece. A questionnaire consisted of 18 items was developed to examine students' knowledge of components and processes of the carbon cycle and ocean acidification. Participants were to answer "agree", "disagree" and "do not know", with the last option given in order to exclude the choice of random response. Each correct answer was coded as "1" and each incorrect answer, as well as the "I do not know" option, as "0". The changes in students' content knowledge were estimated using descriptive statistics performed with SPSS v23.0. Cronbach's alpha was applied to assess reliability.

Findings

The value of Cronbach's alpha showed a low internal consistency of the content knowledge questionnaire before the intervention (α=0.509) probably due to the many missing values, and an acceptable internal consistency after the intervention (α=0.619). The results of the independent-samples T-test showed that the pre- and post-intervention measurement was statistically significant for the knowledge test (Fig. 1).

Before the intervention, the items of the questionnaire concerning the seawater pH change because of the increased CO2, carbon release during decomposition, and the role of carbon in respiration and photosynthesis, were particularly difficult for the students (Table 1). In addition, the students were not aware of the role of decomposers in the carbon cycle, the dissolution of CO2 in seawater, and the release of carbon into the deep during decomposition of dead organisms (Table 1).

After the intervention, students' performance increased in all items, exhibiting statistically significant difference in 13 out of 18 statements (Table 1). However, their scores presented only a slight increase on items concerning the role of CO2 in plants' respiration, the seawater pH change due to increased CO2 levels and the role of decomposers in the carbon cycle (Table 1).

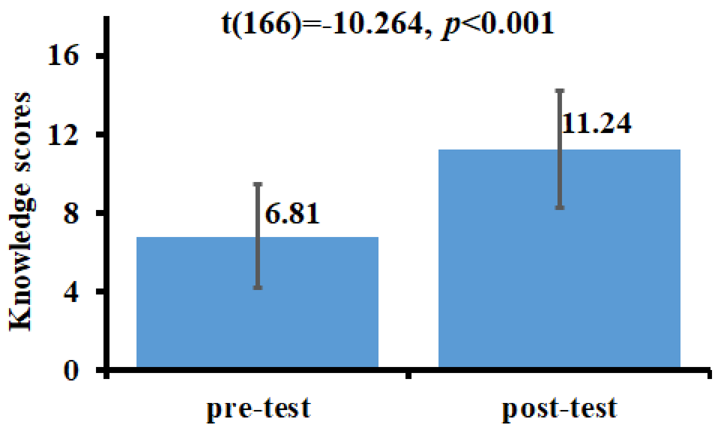

Fig. 1 Students' mean knowledge scores in pre- and post-intervention tests

Conclusions

The findings of the present study showed that primary students after the intervention identified that carbon is being transferred from the atmosphere to the earth systems, both land and ocean. However, they had a difficulty to realize the cyclic nature of carbon cycle, since they misunderstand the output mechanisms of the carbon cycle, mostly plant respiration and decomposition.

Table 1. Relative frequencies of correct answers for the pre- and post-intervention knowledge test, and significance level between the tests

Knowledge questions	Pre-test (n=85) %	Post-test (n=83) %	*p*-level
1. There is carbon in the atmosphere, in plants and animals, in soil, in subsoil and in the ocean	82.1	97.6	***
2. Plants use carbon dioxide from the air for their respiration	16.5	24.1	ns
3. Phytoplankton use carbon dioxide from water in photosynthesis	15.3	60.2	***
4. Humans and animals breathe in oxygen and breathe out carbon dioxide	76.5	86.7	***
5. Carbon is continually recycled in the earth	32.9	55.4	ns
6. Photosynthesis in land and marine plants is part of the carbon cycle	40.0	68.7	*
7. Carbon is released during decomposition	12.3	69.9	***
8. Some carbon gets into the deep ocean when living things in the ocean die	27.4	47.0	ns
9. Decomposers (such as bacteria) break down dead organisms and release oxygen	22.0	36.1	***
10. Fossil fuels are sinks for carbon until they are burned and then they become sources	53.7	71.1	ns
11. Ocean is the biggest carbon sink	43.2	75.9	*
12. Land is the biggest carbon sink	32.9	72.3	***
13. Carbon dioxide in the atmosphere has increased in the last years	66.3	78.3	ns
14. Carbon dioxide is hardly dissolved in ocean water	26.2	51.8	*
15. Increased carbon dioxide emissions have no effect on the ocean environment	51.9	61.4	*
16. Increased carbon dioxide levels increase seawater pH	6.1	24.1	***
17. Increased amounts of dissolved carbon dioxide in the ocean do not affect organisms having shells	50.0	74.7	***
18. Increased amounts of dissolved carbon dioxide in the ocean are harmful for the corals	36.1	68.7	***
Mean percentage	**38.4**	**62.4**	

s: non-significant
*: significant at the 0.05 level
**: significant at the 0.01 level
***: significant at the 0.001 level

Concerning ocean acidification, although students mistakenly interpreted acidification as an increase in pH values and not as a decrease, they realized that excess anthropogenic carbon outputs cause carbon accumulation in the atmosphere, which is transferred to the sea and brings the carbon system out of balance, affecting the calcareous skeleton building capacity of marine organisms. This finding indicates that they realize that humans' everyday actions concerning CO2 emissions may affect ocean acidification and, consequently, the health of the ocean and its inhabitants.

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Teacher students' prior knowledge of water pathways and what they think is essential pupils' knowledge

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Introduction

This study has focused on the pre-service teacher student's prior knowledge they have brought with them into teacher education and their expectations about teaching science in grades 0-6. The knowledge focus of this study is on which level the students can see the body as a system. The water pathway in the body is a scenario that allows seeking knowledge about how students think the different organs and organ systems are linked together (Granklint Enochson et al. 2015; Tunnicliffe 2004) and that it even is difficult among university students to gain knowledge (Granklint Enochson 2023; Clément 2003). The opportunity to learn about the body and its organs has been given during the student's time in school from preschool up to upper secondary school. A large part of the curriculum and textbook content at all stages in the mandatory school system, and some of the upper secondary school courses are about the human body.

Theoretical backgrounds

The knowledge itself is built on by adding further knowledge, i.e. knowledge that we have previously acquired is the basis for generating new knowledge (Ausebel, 1968). However, to build upon this knowledge, the child needs help to understand explanations of different phenomena around them, and they need opportunities to develop their understanding. Students' answers could be interpreted as misconceptions, but sometimes can the student's answers be related to the that science the students are being taught in school does not harmonize with the ideas that are prevalent in their everyday culture (Phelan et al, 1991; Aikenhead, 2006; Lemke, 2001). There is also a possibility that the students have not been introduced to the topic in such a manner that the students have had an opportunity to develop a scientific approach to the content (Phoenix, 2009; Vygotsky, L., 1934/1986).

Research methods

Sample

The participants in the survey are 48 prospective pre-service teachers. The students are enrolled at a Swedish university and are admitted to getting a degree in Master of Arts in Primary Education, either in School Years 4–6 or Pre-School or School Years 1–3. All the students are in year three of a four-year education. The data was collected on their first day of the science course. No one of the students has previously taken courses in biology at the university level.

Table 1. The students as participants in the study.

Pre-service teachers with the aim to teach in:	Number of participants	Female/Male
Grade 0-3	25	20 female, 5 male
Grade 4-6	23	13 female, 10 male

Empirical collection

The empirical data are based on a questionnaire comprising two parts; one consisted of a non-gender-specific human body on which students could draw the path of water through the body, and the other had open questions about their intentions to explain the passage of water through the body to the preschool children. One more open-ended question was given about the importance of drinking water and the pre-service teachers
intentions to tell a student.

Analysis
Analysis of the collected material was categorised according to a system, as described above by (Granklint Enochson et al. 2015), which is based on how close the pre-service teachers' sketches and text being analysed

A. No answer, or answer not related to question.
B. Non-scientific descriptions based on alternative ideas of the organ system.
C. Descriptions following a scientific explanatory model – important parts were missing.
D. Descriptions following a scientific explanatory model – important parts included.

The open-ended questions were mirrored in the pre-service teachers' levels of knowledge about the water pathway e.g. their understanding of connections between organ systems with their understanding of the function of water.

Results
Preliminary results show that category B (Non-scientific descriptions based on alternative ideas of the organ system) and C (Descriptions following a scientific explanatory model – important parts were missing) were the most common answers.

Table 2: Knowledge *categorization*

Pre-service teachers with the aim to teach in:	Category				
	A	B	C	D	Sum
Grade 0-3	4	7	7	7	25
Grade 4-6	5	7	9	2	23
In total	9 (19%)	14 (29 %)	16 (33%)	9 (19%)	48 (100%)

There is no direct correlation between the students' knowledge of the water pathway and the function of water, but there are some statements as the students did that are worth noticing. For example, 12 of the 48 gave a more scientific explanation but 3 of the students missconcepted the function of water and believed that the water was a part of the breakdown process.

Table 2: Pre-*service students believe in the function of water in the body.*

Water breaks down nutrients	The function of water in the body such as transportation of nutrients or regulation of temperature
A: 0 B: 1 student C: 1 student D: 1 student In total 3 students	A: 2 students B: 4 students C: 4 students D: 2 students In total 12 students

The students' question: "What difficulties/restrictions can occur in connection with teaching about the water found in the body, i.e. what problems can arise in the teaching situation?" In response to this question, most of the students indicated general academic reasons. Quite a few were worried about their ability. However, there were only a few 2 students in f-3 and 4 students in F-6 who indicated disinterest in the subject as a challenge.

Discussion and conclusion
According to previous studies is there more non-scientific explanations than among grade 9 students but less than in a study done with pre-service students taught in pre-school. More discussions will be presented at the conference.

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The development of evolution conceptions during a long-term study at the transition from primary to secondary school

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Unlocking Minds: Revealing Students' Preconceptions of Current Biotechnology

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Theoretical background

Biotechnology is a rapidly advancing field with widespread onto whole society. Genetic engineering is a revolutionary force, unlocking new possibilities. Discussing benefits or drawbacks is becoming more and more common. (Kooffreh, et al., 2020). Therefore, there´s more of a shortage of enhancing students' critical thinking and recognizing their preconceptions, and especially misconceptions about the subject matter (Kidman, 2010). The purpose of this research is to identify the main students´ preconceptions and misconceptions in the field of current biotechnology. Misconceptions are strongly held in students´ minds, different from accepted understanding (Hasan et al., 1999). Correcting the misconceptions that students have is vital for achieving their learning outcomes. Moreover, having correct concepts about any phenomenon is the most important ability for making the right decisions in everyday life (Harms, 2002).

Theoretical framework of this study is based on the Theory of Conceptual Change (Posner et al., 1982; Strike & Posner, 1982; Duit & Treagust, 2003) and The Model of Educational Reconstruction (Kattmann et al., 1997; Kattmann, 2009). Components and educational reconstruction consist precisely of the scientific content & student´ preconceptions & structuring of the learning environment.

Research design and methodology

The main research instrument used in the study is a semi-structured interview with individual respondents (Posner & Gertzog, 1982). Questions for the interview were designed based on the content analysis (see Mayring, 2014) of Framework Education Program for Basic Education (FEP BE; Jeřábek & Tupý, 2007) and school textbooks (20 textbooks and 7 workbooks) for lower and upper secondary schools, with a focus on the field of biotechnology. Questions for the interview were validated by 4 experts in the fields of biotechnology, genetics, and didactics of biology. Altogether, the interviews consisted of 28 questions. The questions were divided into four concepts: biotechnology, genetic engineering, genetically modified organisms (GMO), and cloning. Interviews were administered by the author. The interviews were gathered from pupils from the 9th grade (n = 20) at lower secondary school (14 - 15 years old) and students from the 12th grade (n = 20) at upper secondary schools (17 - 18 years old) in the Czech Republic. All the interviews were recorded on a dictaphone and transcribed. Data were analyzed in MAXQDA 2022, a data analysis software. The gathered data were analyzed both qualitatively and quantitatively. For the qualitative analysis, the Grounded theory (Strauss & Corbin, 1999); inductive coding was used. The quantitative analysis was based on the absolute and relative abundance of a particular category obtained from the qualitative analysis. An independent Students'-test was used to compare the knowledge of 9th graders and 12th graders.

Findings & Conclusion

The prevailing misconceptions in the study encompass both 9th (40%) and 12th (70%) grade students perceiving robotics or machinery as an outcome of biotechnology, rather than its inherent connection to living organisms. Although 75% of 9th graders recognized genetic engineering's involvement in DNA manipulation, 80% lacked a comprehensive understanding of this concept. Furthermore, concerning genetic engineering, 35% of 9th graders incorrectly believed it to be linked to "genealogy". Additionally, 80 % of 9th graders and 40 % of 12th graders claimed that GMOs have only negative consequences for the environment. Significant differences were not confirmed in any of the obtained data. Even though there may not be significant differences between the two groups, findings revealed that students from both groups don't have a contextual understanding of the topic. Specifically, when students possess a basic knowledge of biotechnology, they encounter challenges in interconnecting it with other concepts, such as genetic engineering and GMOs.

In the realm of biotechnology education, understanding students' preconceptions and misconceptions is paramount. By pinpointing these conceptual barriers, we can create a targeted and effective teaching strategy, ensuring that students not only learn the correct concept and relearn where necessary. This tailored approach paves the way for a deeper and more accurate understanding of biotechnology, bridging the gap between students' prior knowledge and scientific concepts, and fostering a new generation of informed and innovative minds in this dynamic field.

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"There is someone blowing away all the leaves" – Multilingual students' conceptions about decomposition of leaves

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Theoretical background:
Students' conceptions are crucial for students' scientific content learning (Amin et al., 2014). For the past decades, this topic has been of great research interest. Following the theory of moderate constructivism (Duit, 1996) and conceptual change (Duit & Treagust, 2003), students' conceptions can be changed/expanded during the learning process towards scientifically appropriate conceptions. Although conceptions are always individual and experience-based(Amin et al., 2014), current research rarely includes individual information of the students. Thus, a differentiation of the existing conceptions based on various factors such as the first language or the cultural background is only possible to a limited extent.
In addition, language plays an important role in scientific content learning: Students need language to structure their knowledge and build up conceptions. Up to now, a connection between the field of multilingual learners and students' conceptions is still missing.
This study exemplarily focuses on the phenomenon of decomposition of leaves. Recent studies present common students' conceptions, e. g., the accumulation of leaves as a result of a missing decomposition of leaves (Helldén, 2004) or the fact that students often do not see the relevance of microorganisms in this context (Hammann & Asshoff, 2014).

Key objectives:
Based on the current state of research, the study aims to differentiate students' conceptions about decomposition of leaves in terms of students' first languages. To reach this aim, the following research questions will be answered:
(1) Which conceptions do students with different first languages show about decomposition of leaves?
(2) Which differences regarding their conceptions can be seen between students with different first languages?
Due to the increased linguistic-cultural heterogeneity in schools in recent years and thus the additional individual areas of experience, it can be assumed that the diversity of students' conceptions has increased in comparison to the state of research.

Research design and methodology:
The explorative study consists of guideline-based interviews as well as questionnaires on demographic, learning-motivational and language-biographical aspects were carried out with 24 students.
The questionnaires were evaluated by means of descriptive analyses. The interviews were then transcribed and analysed in a three-step process:
(1a) content-structuring and (1b) evaluative Qualitative Content Analysis according to scientific appropriateness (Kuckartz, 2014), and (2) Systematic Metaphor Analysis (Schmitt, 2005).
By combining those methods, it is possible to get an overview about students' individual conceptions regarding different aspects of decomposition of leaves. This also offers insights if the conceptions are scientifically appropriate or not and the metaphorical language in relation to students' language biography.

Findings:
The interviewed students were 15-17 years old and attended the 9^{th} or 10^{th} grade. In total, the students had 12 different combinations of first languages (L1). Seven students were already taught about decomposition of leaves.
Two aspects of the phenomenon will be explained here as examples:
Reasons for decomposition of leaves: The explanation about what is happening during decomposition of leaves varied individually. Most students were able to identify different organisms as reason for decomposition of leaves. The students outlined especially insects or arthropods as organisms and nearly one third of the students also mentioned microorganisms. None of the students connected decomposition of leaves with fungi as destruent. Six students (L1 = German) do not mention organisms as reason at all. For them, abiotic conditions are reasons for decomposition.
Effects of missing decomposition of leaves: Most students outlined an accumulation of leaves as an effect of missing decomposition of leaves. However, they were mostly not able to outline the subsequent

effects as interruption of nutrient cycles. Next to these common and previously in the literature described conceptions, there were also students highlighting that there are no negative effects of missing decomposition of leaves. One student (L1 = Arabic) explained that there is no need for decomposition as there are people with leaf blowers removing the leaves.
Another interesting aspect was that approximately one third of the students (various L1) are not talking about "decomposition" during the interview. They were more likely to talk about a change of the shapes and colours of the leaves.

Conclusions:
This study identified undocumented as well as scientifically (in)appropriate students' conceptions regarding the phenomenon of decomposition of leaves. The identified conceptions vary more than those of former studies about students' conceptions do.
The findings show that the conceptions differ more individually than with respect to a specific first language. Due to the sample size, it is not possible to show correlation between language and conception. However, the study shows an overall tendency that the presence of linguistic- cultural heterogeneity increases the diversity of conceptions.

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Identification of conceptual difficulties and ideas about food in students of primary education

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Theoretical background or rationale

The ideas with which students come to classrooms have aroused great interest in all areas of knowledge for decades. In the case of food, some authors highlight that the conceptions that students have at the first educational stages are fundamentally conditioned by what they see at school or on television and, also, by what their family members and health professionals tell them.

In recent decades, we have found numerous works that address the ideas of students at different educational stages in relation to food (Cabello et al., 2018). Some of them have been questioned regarding the validity and reliability of the data, due to the methodological strategies applied, highlighting questionnaires and interviews, among others. In this way, this work is proposed through the observational methodology approach, which has given good results, for example, for the study of discourse and the identification of scientific skills of students in the classroom (Mazas et al., 2021).

Key objectives

To know the main conceptual difficulties and types of ideas about food that, in a natural classroom context, are expressed by students in the 3rd year of Primary Education in a public school.

Research design and methodology

To achieve the stated objective, an instrumental case study has been carried out in which the singular unit of analysis has been the 3rd year EP students of a public school in a rural neighborhood near Zaragoza (Spain). During the 2019-2020 academic year, a teaching and learning sequence (TLS) was carried out in which food content was worked on within the subject of Natural Sciences. The general dynamics of the sessions consisted, first of all, of carrying out a short introduction to the contents that the teachers had scheduled to teach that day in the classroom. Afterwards, several questions were posed to find out the previous ideas that the students had about those contents. Finally, considering the students' answers, the teachers gave theoretical explanations and proposed carrying out activities on food contents. All sessions were recorded in audio and video and, subsequently, transcribed to perform an analysis of all transcriptions using self-developed templates. The analysis has allowed us to know some conceptual difficulties and ideas about nutrition that the students had, which were revealed through the answers they gave to the questions posed by the teachers and from comments that emerged in the classroom.

Findings

The analysis carried out has allowed us to identify a total of 166 statements expressed verbally by the students. These have been grouped according to the ideas or conceptual difficulties they represent and those that had similar meanings have been unified. Thus, up to 8 categories have been identified that collect the main conceptual difficulties (3) and alternative ideas (5) presented by the students. In tables 1 and 2 some examples of the conceptual difficulties and ideas about nutrition that the students expressed are shown (the statements that appeared as a result of emerging comments in the classroom have been marked with an asterisk (*).

Table 1. Examples of conceptual difficulties expressed by students

Conceptual difficulties	Examples
They do not adequately relate the food to its main nutrient	• The nutrient in fruits and vegetables is protein • The nutrient in cereals is gluten / lactose / carbohydrates • Carbohydrates give us milk.
They do not know the groups to which the foods belong as well as the types of foods	• Salmon is a hake • I didn't know that salmon could be sold in the shape of a fish* • Chewing gum is sugar* • Peas are cereals/vegetable/fat/fruit
They do not understand the meaning of nutritional graphic representations. (food pyramid and wheel)	• Sweets are at the top because it is what they make the most money from* • Breakfast cereals are at the top because they contain chocolate* • The green color with which fruits and vegetables appear indicates that they are healthy.

Table 2. Examples of ideas about food expressed by students

Alternative ideas	Examples
They think that there are "good and bad," "healthy and unhealthy," or "healthy and unhealthy" foods (and nutrients)	• There are healthy and bad foods • Sugar is a bad nutrient • Sliced bread is worse than normal bread because it has more sugar • There are good and bad fats* • The fat in nuts is good* • Olive oil is good* • The eggs are healthy* • Fish is healthy* • The sausages are very bad*
They think that different foods have different effects on the body.	• Milk proteins give us strength / give us muscles • Proteins from meat, fish, eggs and legumes give us strength / give us muscles • With sugar you activate yourself and then you get a crash* • Milk is good for bones • Carrots are good for your eyes* • Tomato takes away your wrinkles* • When you eat banana it makes you not thirsty*
They think that there are foods that cause diseases, allergies and/or food intolerances	• Food allergies prevent people from eating certain foods* • An example of a food allergy is an egg/nut allergy* • Cavities appear from eating too many sweets • Hypertension is favored by the consumption of foods with a lot of salt • Lactose and/or lactose intolerance is dairy
They think that food hygiene is the same as personal hygiene.	• Drink water after lunch and dinner • Wash your face and digest • Brush your teeth and go to the bathroom
They think that the foods that are advertised on television (or advertised, in general) usually have bad things.	• Foods advertised on television contain salt, fat and sugars • The foods advertised on television do not have the nutrients that highlight the messages that appear in the advertisement • The message "moderate consumption" means that the food is unhealthy • Sliced bread is worse than normal bread because companies make it and they put bad things in it • Nesquik brand breakfast cereals have a lot of sugar* • Nocilla is bad* • Yatekomo brand noodles contain very strange things.

Conclusions:

The use of audio and video recordings collected in a natural classroom environment together with the subsequent analysis of their complete transcriptions has proven to be useful to identify conceptual difficulties and alternative ideas about food that arise during the learning of these contents.

Of all of them, some that have already been identified in research by various authors stand out, such as the difficulties to diferenciate between food and nutrient or between the concepts of food and nutrition. Regarding nutritional graphic representations, such as the pyramid and the food wheel, the difficulties that girls and boys in the 3rd year of Primary Education have in understanding them are evident.

Regarding the effects that foods and nutrients have on the body, some students try to bring the ideas expressed closer to scientific references ("there are good fats like olive oil", among others). Sometimes they express ideas strongly conditioned by popular beliefs or social prejudices such as "carrots are good for the eyes" and "companies do it and put bad things in it", among others. Finally, students give a prominent role to food advertising and many confirm the influence of certain advertisements on their purchasing decisions.

In conclusion, as reflected in this work, the environment that surrounds students plays a very important role in the construction of knowledge about food and, in addition, can cause many of their ideas to be partial or inappropriate. In this way, it is necessary that in the classrooms these conceptual difficulties and alternative ideas are detected from the first educational stages and different strategies are implemented to facilitate the development of food competence, as well as critical thinking.

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Adaptation of a simulation-based video learning environment to train biology teachers

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Theoretical background or rationale

The use of real-life classroom videos has a long tradition in teacher education (Seidel, 2022). Especially their practical relevance is decisive for the learning gains of student teachers. In contrast to written descriptions of lessons, videos make it possible to depict the complexity of what happens in class and to analyse it intensively by watching it several times (Sherin et al., 2008). Particularly in the university teacher education, student teachers lack the necessary practical experience to diagnose their own teaching actions, whereby classroom videos can serve as a bridge between theory and practice (Gaudin & Chalies, 2015; Weger, 2019). The simulation-based video learning environment *DiKoBi* (Kramer et al., 2020) was developed to train students' diagnostic competences in relation to teacher action. The goal is to develop their Professional Vision (Seidel & Stürmer, 2014). The simulation includes scripted classroom videos that show a biology teacher acting in challenging teaching situations. The task of the students is to analyse the videos with regard to the teacher's actions. The analysis contains three tasks: (1) describe and (2) explain the challenging aspect identified in the videos by including theoretical references and (3) generate alternative strategies. The students go through this micro-process for five aspects of biology-specific instructional quality: cognitive activation/situational interest, use of technical language, use of experiments, use of models and conceptual understanding.

Key objectives:

Since the training of Professional Vision is not only important in the context of pre-service teacher education, but is also an elementary component of teachers' professional competence (Seidel, 2022), the question arises to what extent the existing simulation *DiKoBi* (Kramer et al., 2020) can also be integrated into in-service teacher training. The aim of the project is to design a simulation that meets the expectations of in-service teachers and supports them to diagnose their own teaching activities on the basis of theory and to use alternative strategies in their own teaching.

Research design and methodology:

The adapted simulation focuses on the alternative design of different aspects of instructional quality. This enables teachers to analyse teacher action in the video and to generate alternative strategies based on theory. The aspect is considered from different theoretical perspectives with associated video sequences, which are then weighed against each other. For example, cognitive activation/ situational interest is developed with the concepts of context orientation and problem orientation. The teachers have the opportunity to view a summary of the concepts beforehand. Afterwards, the different design options can be viewed (several times) as scripted videos. In the end, the teachers are asked in a kind of writing conversation in the simulation to watch the two videos individually and to evaluate them with regard to the teachers' actions in relation to the concept. They are also asked to make a reasoned choice which of the options they prefer and which alternative strategies are available to the options shown. In this process, teachers can react to the answers of other participants. In the long run, a discourse should develop across all participants and the best alternative courses of action should be identified.
The simulation *DiKoBi* is embedded in an in-service training series on the five aspects of instructional quality mentioned above. There is a separate module for each aspect. Each module is divided into 4 phases: Input in presence on the respective aspect of teaching quality, training and discussion of the aspect with the help of the simulation at home, testing of the aspect in teaching practice and final reflection in the group. The practical relevance of the training is ensured by training the content of the training in the simulation and testing it in the classroom. The reflection before entering the next module helps the teachers to diagnose their own teaching practice.
The fit of the simulation to the expectations of the teachers will be investigated through feedback from the teachers. In order to pilot the simulation, biology teachers will be questioned qualitatively about the usefulness of the content shown and the technical usability of the simulation. Subsequently, a larger number of teachers will be examined in the main study. For this purpose, the usability of the digital learning environment as well as the satisfaction of the teachers will be measured with short scales. In addition, the written answers from the writing conversations of the teachers, who have worked on the simulation, will be evaluated.

Findings and Conclusions:
From this it can be concluded whether the teaching action can be diagnosed and adequate action alternatives can be chosen according to the teachers' Professional Vision. The simulation will be piloted in spring 2024. First results of a pilot study will be presented.

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A biology congress in class: contributions to the use of data and formulation of conclusions

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Theoretical background or rationale

Science education should promote the enculturation of students in science through the incorporation of scientific practices (inquiry, modelling and argumentation) in class. Students need to be given opportunities to formulate hypotheses based on their models, design and carry out inquiries to test them and use patterns in data to explain phenomena (Windschitl et al., 2008). They should also interpret data and turn them into evidence so they can make conclusions and establish differences between results and conclusions, which they frequently confuse (Zohar, 1998). Duncan et al. (2018) criticised the poor use of authentic data (multiple, low-quality, complex) in science classrooms. Using multiple data, which include anomalous data or contradicting data can lead students to take different strategies such as ignoring or rejecting them (Chinn & Brewer, 1998).

One possibility for the students to manage different data is to share and discuss them through participating in scientific congresses that involve communicating the results (Domènech- Casal, 2014). We analyse how a biology congress in class helps Pre-service Teachers (PSTs) to improve the conclusions they draw, the reference to the infection model in them and the use and discussion of data from other sources (other groups).

Key objectives:

The research questions (RQ) are the following:

RQ1. How do PSTs draw conclusions in poster communications and written reports about bacteria produced infection?

RQ2. How do PSTs include the infection model in poster communications and in written reports?

RQ3. How do PSTs use other groups' data in their conclusions in the written report?

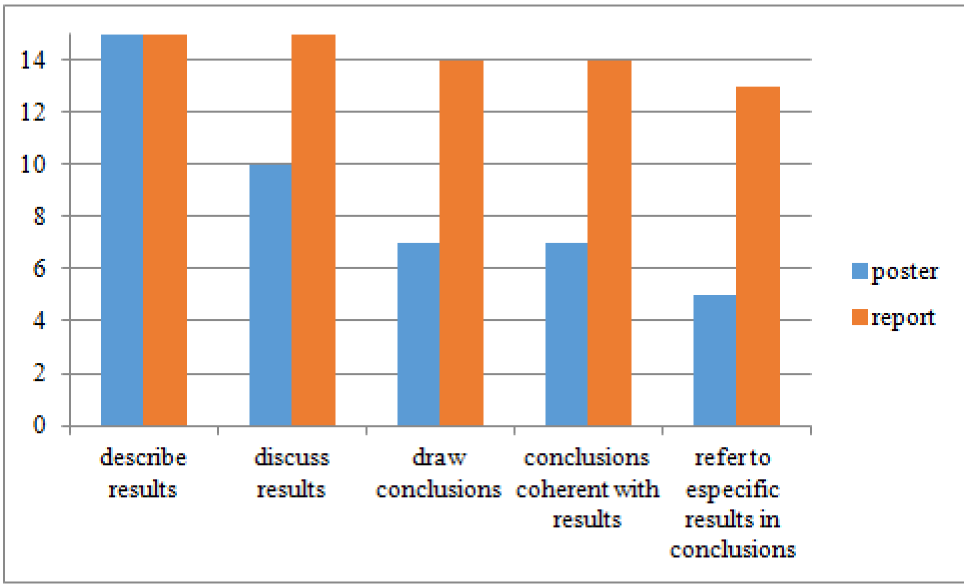
Research design and methodology:

The research was conducted in two groups of a science teaching course in the third year of an Undergraduate Grade on Elementary Education, during the second semester of 2022-23.

54 PSTs (15 groups) participated in a model-based inquiry sequence that included designing an experiment. After answering an initial questionnaire about urine infection and its cause, the PSTs gathered in groups of three or four people and searched for information, focusing on the bacterium E. coli. After that, they designed an experiment to try to test in which conditions E. coli would grow. The PSTs had to design different situations, predict where E. coli would grow and explain the reason. Once in the lab, each group sowed the E. coli bacterium in petri dishes in different incubation conditions for 24 h. Then, after observing the dishes, they prepared a communication of their research for a poster session that was performed in class. Finally, PSTs were asked to contrast the results obtained by the different groups, try to respond to the hypotheses initially raised and produce a final report.

Data were taken from the posters and the final reports (Results and Conclusions). For addressing RQ1, it was taken into account if the groups were describing or discussing the results or if they went to draw conclusions (Zohar, 1998). For responding RQ2, it was analysed whether the students included the scientific model by mentioning the agent that causes urine infection (bacteria or E. coli) and its nutrition and/or reproduction. For addressing RQ3 it was assessed whether they took into account the information obtained during the congress in their reports. For that purpose, it was considered if they included data of other groups that support or contradict their data and how they used those contradictory data.

Findings:
Figure 1 shows the results for RQ1.
Figure 1. Number of posters and reports meeting the criteria. Figure 2 shows



the results for RQ2:

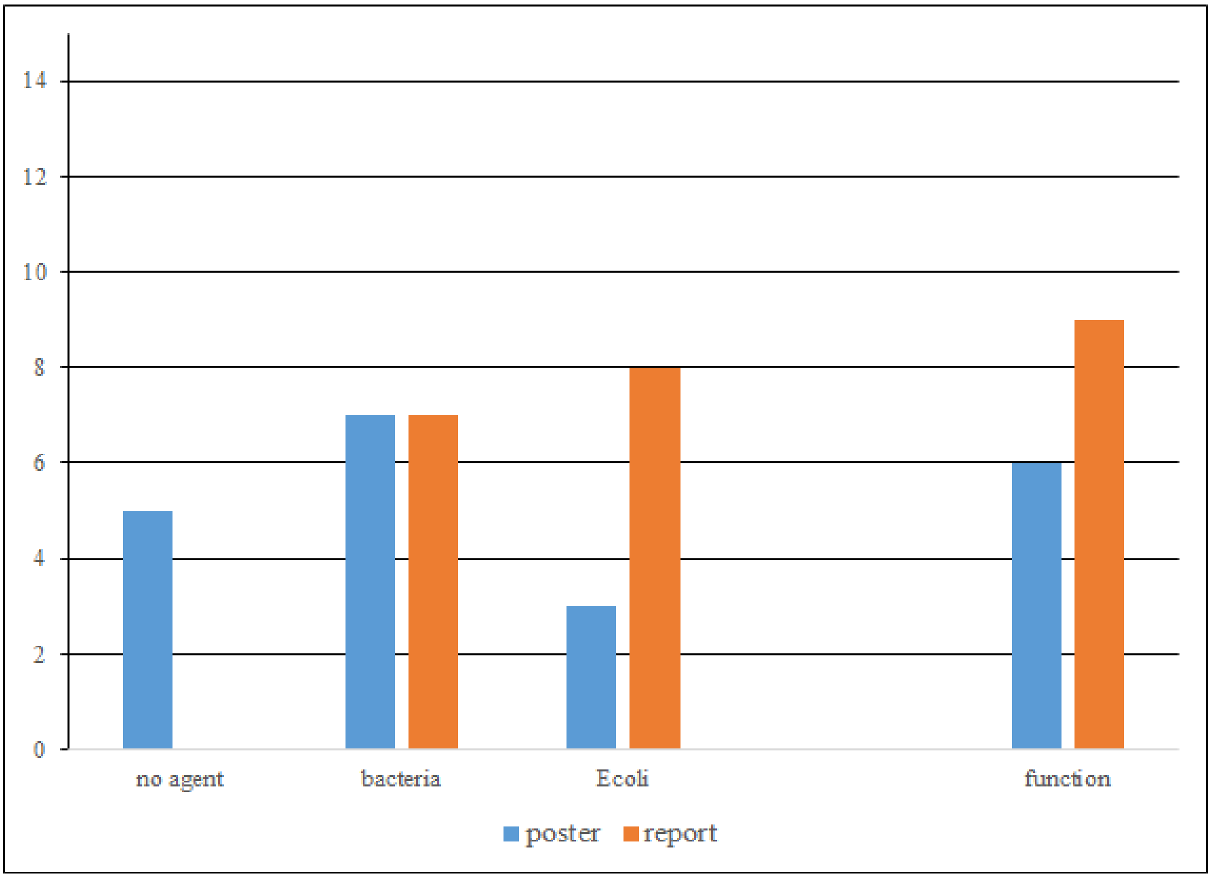


Figure 2. Number of posters and reports meeting the criteria. Table 1 shows the results for RQ3:

Table 1. Number of groups making diverse actions with the results of other groups.

Action	Number of groups
Mention results of other groups	14
Add results of variables not directly investigated	8
Groups with supporting results	15
Incorporate supporting results	11
Groups with contradictory results	13
Mention contradictory results	8
Discuss contradictory results	5

Conclusions:

Results show that all PSTs described results both in posters and reports, and that they discussed results and drew conclusions differentiating between results and conclusions (Zohar, 1998), mainly in the reports. This was not found that much in the posters, unlike in the study of Domènech-Casal (2014). In the case of including the infection model, all the reports mentioned the agent and 60% its functions, and in the posters 67% mentioned the agent and 40% its functions. while only 10% referred to the model in the study of Domènech- Casal (2014). The congress gave all the groups the possibility of adding new results, and 14/15 did so. 11/15 groups (73%) that had the possibility of incorporating supporting results in their conclusions did it. What is more remarkable is that 8/13 groups (62%) did not ignore contradictory results as other studies found (Chinn & Brewer, 1998) and some of them discussed them and justified them alluding to experimental errors and other variables.

It can be concluded that the congress contributed to the formulation of conclusions, to making references to the model, and to the generation and use of multiple data (Duncan et al., 2018), even when they are contradictory.

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Using a digital simulation to foster diagnostic competence of in-service biology teachers during professional development

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Theoretical background:
In the educational sciences, diagnostic competence is considered a fundamental element of teachers' professional competence to support students constructively and adaptively in their learning (Aufschnaiter et al., 2015; Baumert & Kunter, 2006). Referring to the competence-as-continuum model of Blömeke et co-authors (2015) diagnostic competence includes situation-specific skills that enable teachers to assess the students' current levels of learning levels and underlying concepts of comprehension. Based on the students' performance diagnosis, instructional strategies can then be derived and implemented to constructively support students learning (Aufschnaiter et al., 2015; Baumert & Kunter, 2006). According to Blömeke and co-authors (2015), who emphasised the process-based character of professional competence, diagnostic competence can be fostered.
The SCR^{Bio} (Fischer et al., 2022) has been designed to measure and foster diagnostic competence of pre-service biology teachers in domain-specific contexts. Given the potential of similar digital simulations (Codreanu et al., 2020; Stürmer et al., 2021) to foster diagnostic competence, the use of the SCR^{Bio} appears as promising opportunity to promote diagnoses outside (e.g. through the simulation) and inside the classroom (e.g. by diagnostic questioning). We aim to establish the SCR^{Bio} among in-service biology teachers during preparatory service as well as during professional life focussing on the following research questions.

Key objectives:
RQ1: How do the professional development (PD) programs affect the diagnostic competence of in-service biology teachers?
RQ2: Does the effect size on the diagnostic competence differ between PD programs integrating the SCR^{Bio} and the sole use of the simulation?
RQ3: Which aspects of motivational orientation are addressed during the use of the SCR^{Bio} and are relevant moderating factors for improving teachers' professional diagnostic competence?

Research Design and Methodology:
In order to address the key objectives, a pre-post-baseline-intervention study was designed to compare the effect of using the validated digital simulation SCR^{Bio} without (baseline) or combined with PD programs (intervention) on the diagnostic competence of biology in- service teachers. The concepts of the PD programs are based on evidence for effective PD obtained in educational sciences involving e. g. motivation for reflection, participant orientation, and coherence (Barzel & Selter, 2015; Desimone & Garet, 2015; Lipowsky & Rzejak, 2021). The concepts take different facets of diagnostic competence into account (Aufschnaiter et al., 2015). The effectiveness of the PD program and the use of the SCR^{Bio} will be investigated empirically and distinguished by comparing the diagnostic competence in the baseline group to the intervention group using a pretest-posttest-design. Diagnostic competence is operationalised in terms of accurately distinguishing scientifically correct from wrong students' answers, ranking students' competence levels and identifying factors that hinder learning progressions such as misconceptions. For controlling against effects of location the study will take place at different German federal states.

Expected findings:
Since the data collection is scheduled to be finished in summer 2024, the following findings are to date hypothetical orienting on existing evidence, and conclusions cannot yet be drawn finally. Considering the effects of using the SCR^{Bio} with pre-service biology teachers (Fischer et al., 2022), we expect the SCR^{Bio} to be a valid tool to measure and foster diagnostic competence of in-service biology teachers.
With respect to the PD programs we expect even higher effects on diagnostic competence of the in-service biology teachers compared to the sole use of SCR^{Bio} since they allow instructional support in a more adaptive manner. For instance, the relevance of diagnosis is emphasised from multiple perspectives

and the application of diagnostic competence in school is specifically addressed and exemplified. In a meta-analysis of how different types of scaffolding impact diagnostic competence, significant effect sizes on diagnostic competence were shown for instructional support such as diagnosis-specific prompts and inducing reflection on diagnosis for teachers with high prior knowledge (Chernikova et al., 2020). Similar to Kron et al. (2022), we expect the approach to allow the identification of motivational orientation aspects that are the relevant moderators for the development of diagnostic competence.

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Environmental education: Attitudes

Elementary school students' development of hope via an educational environmental project for climate change

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Introduction

Studies have indicated that many young individuals express concerns and pessimism about the global future, especially when it comes to the resolution of global issues such as Climate Change (Kelsey et al., 2021). On the contrary, a strong sense of hope is more likely to actively engage persons in actions against climate change (Kerret et al., 2016). Therefore, cultivating hope for the global future should be a vital component of environmental education programs (Ojala, 2021). Hope is not only a pleasant emotion but also a driving force. According to Kerret et al (2016), environmental hope consists of three components: (1) Pathway Thinking: People believe on their own capability to generate different workable routes leading to their goal of protecting the environment, (2) Agency Thinking: People have the motivation to use these routes to achieve that goal, (3) Social Trust: the sense that other individuals or social groups can be relied upon to collaborate in seeking solutions to environmental problems.

Within the above line of reasoning, we have developed and implemented an educational environmental project for climate change, aiming to cultivate environmental hope.

Specifically, this research aims to answer the following question: 1. How is hope cultivated through an educational environmental project for climate change?

Methodology

Participants

Twenty-seven students, 10-11 year old (5th grade of the elementary school), from a public urban school, were involved in this research.

The educational project

The first stage of the project (September-December 2022) included activities based on Oxfam Education (2022) teaching resources on climate change education. Students learned about climate crisis and studied successful environmental actions at national and international level. This stage also include sessions during which participants developed skills and they learn methods for calculating their school's carbon footprint.

During the second stage of the project (January-June 2023), participating students design and implement a plan for reducing their school's carbon footprint, encouraging students from other grades to participate as well. During that stage external motives, such as rewarding students with tokens that they could exchange for vegetables from a local grocery store, were introduced.

Data Collection

The data were collected through group semi-structured interviews, before and after the end of the project. The open-ended core questions of the interview were extracted (and modified for the purpose of the present research) from the tools derived by Snyder et al. (1997), Ojala (2012) and Kerret et al. (2016) (see Tables 1, 2 and 3).

Data Analysis

Participants initial (positive or negative) responses to the main questions of the interview were recorded and their frequency was calculated. The arguments and ideas expressed during the interviews were classified in categories responded to the components of hope, i.e. 'pathway thinking', 'agency thinking' and 'social trust'.

Findings

As it is shown in Tables 1, 2, and 3 the project caused changes in all three components of hope, especially concerning 'agency thinking' and 'social trust' components.

Students' statements during the interviews showed how they were affected by the project. For example, a girl said after the project: "*Yes, we can do it just like the other kids of our age you showed, we can take such actions.*" (Pathway Thinking). The same girl's reaction before the project was: "*It's difficult for me to change the temperature, to lower it...*".

When students start acting in their school, trying to reduce its carbon footprint, they start feeling competent to address climate change. A boy said: "*We can address climate change because now we know all the things we've learned that others don't know*". A girl said: "*Now I feel that I can handle climate change. We* *saw that we could reduce a lot of carbon dioxide and help in facing climate change a bit.*" (Agency Thinking). Finally, students learned to trust their classmates (Social Trust). According to a boy, the whole school community could contribute to the reduction of carbon dioxide.

Conclusion

Mogensen and Schnack (2010) state that positive psychology programs are beneficial when they include past experienced successes. This is an advice that we followed in our project with promising results. Furthermore, the project promoted the participation of the whole school community in reducing carbon dioxide emissions. Taking actions as a community rather than individually enhances the likelihood of success in achieving desired goals (Kelsey et al., 2021). Finally, it should be noted that external motives played an important role in developing participants engagement in action and the sense of hope: rewarding students with tokens that they could exchange for vegetables from a local grocery store and acknowledging their monthly results in reducing their carbon footprint encouraged them to strive even harder to achieve their goals.

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Table 1

Pathway Thinking

Questions	Pre (n=27)			Post (n=27)		
	Yes	**No**	**No answer**	**Yes**	**No**	**No answer**
Do you think there is a way to address the problem of climate change?	16	5	6	18	1	8
Can you think of many ways to address climate change?	3	5	19	20	2	5
Do you want to address climate change?	21	1	5	22	0	5
If others don't want to address climate change, can you think of ways to address it?	19	2	6	21	1	5

Table 2

Agency Thinking

Questions	Pre (n=27)			Post (n=27)		
	Yes	No	No answer	Yes	No	No answer
Do you think you are capable of addressing climate change?	7	16	4	19	0	8
Do you think that other children of your age are capable of addressing climate change?	11	8	8	13	6	8
Do you think you are more capable than other children your age in addressing climate change?	0	17	10	8	10	9
Do you think that your actions taken now to save the environment, will continue being helpful in saving the environment and addressing climate change in the future as well while you will be older?	10	5	12	17	3	7

Table 3

Social Trust

Questions	Pre (n=27)			Post (n=27)		
	Yes	No	No answer	Yes	No	No answer
Do you think that researchers and scientists will be able to address climate change?	16	3	8	21	1	5
Do you think that politicians in countries are interested in addressing climate change?	5	11	11	9	14	4
Do you think that people, and members of environmental interest groups can help in addressing climate change?	10	8	9	15	1	11
Do you think that your entire school can help in addressing climate change?	18	5	3	16	0	11

Green facades in school: the role of environmental attitudes for learning about a specific topic

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Theoretical background

Improving pro-environmental attitudes and knowledge is a central concern of our time, especially for young people in cities, where about half of the earth's population lives. Both (knowledge and attitude) are essential to deal with environmental issues such as climate change, pollution and loss of biodiversity. The relationship between knowledge and pro-environmental attitudes, has also been investigated (Kaiser et al., 2008; Roczen et al., 2014).

This relationship may be explained with the Campbell paradigm and its relevant modifications (Baierl et al., 2022; Henn et al., 2019). According to this paradigm, two driving forces determine the likelihood that a pro-environmental behavior will occur: attitude and costs. The higher the attitude, the more likely the behavior. Conversely, the higher the costs, the less likely the behavior. Furthermore, attitude determines whether a behavior is shown or not and how rigorously or with which intensity it is implemented (Henn et al., 2019). Recent studies (Baierl et al., 2022) adapted this dual role of attitude for learning about environmental topics as a form of pro-environmental behavior. Attitude firstly controls the likelihood of learning about a specific topic, and secondly, the intensity with which this is done (increase in knowledge).

A specific topic relevant to environmental issues in cities is Green Facades. Green Facades are an example of Nature Based Solution because they contribute to mitigating environmental problems through several effects as shown in literature (Pérez et al., 2014), (Marchi et al., 2015), (Perini & Roccotiello, 2018), (Pérez et al., 2018), (Chiquet, 2014). Moreover, the educational relevance of Green Facades suggests their use as an exemplary topic to learn about environmental issues and possible solutions (Pacini et al., 2022). Therefore, we applied the Campbell Paradigm (Baierl et al., 2022; Kaiser et al., 2010) to Green Facades.

Key objectives:

The primary purpose of this study was to test whether pro-environmental attitude is relevant for learning about a specific environmental topic (Green Facades) and, if so, whether the newly acquired knowledge is stable over time.

Research design and methodology:

A didactic intervention on Green Facades was designed and implemented in two waves (March/April 2023 and September/October 2023) at the University of Cologne by inviting high school students from different schools.Students were introduced to the Green Facades topic, linking it to general environmental issues. The core of the session were four experimental stations showing, in laboratory conditions, the effects of Green Facades in cities. Finally, take away materialwas distributed proposing follow-up activities.
The effect of the intervention on pro-environmental attitude and knowledge was evaluated through questionnaires administered at three measurement points T0 (one week before the intervention), T1 (just after the intervention), T2 (one month later).

All three questionnaires included questions on attitudes (general pro-environmental and Green Facades-specific ones) and on knowledge about Green Facades. Additionally, the T1 questionnaire included questions about students' participation in the different experiments, while the T2 questionnaire included questions about optional follow-up activities. The measurement of general pro-environmental attitude relies on two instruments for adolescents, one based on behavioral self-reports (Kaiser et al., 2007), the other based on evaluative statements (Baierl et al., 2022; Bogner & Wiseman, 1999, 2006; Wiseman & Bogner, 2003). Green Facades-specific attitude and knowledge questions were self-developed as well as those on follow-up activities.

The study was conducted as a within-subjects design. In an initial analysis, the change of both pro-

environmental attitude and knowledge over three points of measurement was investigated. The formalization of the Campbell Paradigm is the Rasch model (Rasch, 1960/1980) which was used to determine pro-environmental attitude and knowledge. Specifically, to enable a direct comparison between the different points of measurement, the stacking method was used (Kolen & Brennan, 2014). For this method, every item is included once and every person up to three times (T0, T1, T2) in the analysis. This way, it is possible to directly compare a person's attitude/knowledge at T0 with that at T1 and T2 as they are in the same metric. Furthermore, multiple linear regression was used to test the effects of prior pro-environmental attitude and knowledge (T0) on knowledge after the intervention (T1/T2).
The total sample of students (N = 86) from three schools was used to estimate attitude and knowledge. For the main analyses, only the subsample of 60 students (M_{age} = 13.68, SD_{age} = .79, n = 20 females, n = 39 males, n = 1 NA) who completed all three questionnaires was used.

Findings:
The analysis of the results is completed only for the first wave, as the second wave is in progress. The pro-environmental attitude measure showed a satisfactory person-separation- reliability of *rel* = .80. The person-separation-reliability of the knowledge measure is less satisfactory at *rel* = .55, however comparable to literature (Baierl et al., 2022).

An overall increase in knowledge was observed between the different points of measurement, $F(2,177)$ = 9.31, $p < .001$, $\omega^2 = .08$. Post-hoc Bonferroni adjusted t-tests revealed that there was a significant increase between T0 (M = 0.81, SD = 0.52) and T1 (M = 1.18, SD = 0.59), $p <$ .001, but no change was detected between T1 and T2 (M = 1.27, SD = 0.73), p = .53, showing a stable knowledge gain.

The pro-environmental attitude did not change overall between T0 and T1, or T2, respectively, $F(2,177) = 0.60$, $p = 0.55$.

The regression model showed a significant effect of prior knowledge, $\beta = .42$, $t(57) = 3.80$, $p <$ .001, as well as pro-environmental attitude, $\beta = .32$, $t(57) = 2.83$, $p < .001$, on knowledge after the intervention, $F(2,57) = 16.98$, $p < .001$, $R^2adj = .35$. Students with higher prior knowledge had higher knowledge after the intervention. Moreover, pro-environmental attitude had an effect beyond prior knowledge: the higher the attitude the more students learned.

Conclusions:
Change in knowledge depends on 1) prior knowledge (the higher the knowledge at T0, the higher the knowledge at T2) and on 2) prior environmental attitude (the higher the attitude at T0, the higher the knowledge at T2 beyond the prior knowledge). The results are in line with prior findings on the role of attitude for knowledge gain from secondary analyses (Baierl et al., 2022). Further developments are expected after the second wave that is enlarging the sample with students from 4 other schools.

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Students' Perspectives and Affective Dispositions on Current and Future Climate Change Education

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Theoretical background

Despite decades of scientific and political effort, the climate crisis continues to threaten global ecosystems and human well-being (Steffen et al., 2015). Whilst the window of opportunity to mitigate and adapt to its effects is "rapidly closing" (IPCC, 2022), researchers identified climate change education (CCE) as a key player for a climate-just transition (e.g. Otto et al, 2020). In this context, students are crucial "change agents" (Kuthe et al., 2019; Authors, 2022) amplifying climate change (CC) knowledge and action. But recent CCE literature highlight challenges. On one hand the global "Fridays for Future" movement showcases the young generation's commitment to climate protection and political influence (Nash & Steurer, 2021). Nonetheless, systemic challenges within the education sector, like the lack of climate-specific curricula hinder institutional promotion of CCE. The urgency of the topic, a highly complex and interdisciplinary science content, psychological challenges and a contentious social discourse marked by science scepticism and fake news present unique challenges for students acting as CCE multipliers (Authors, 2022). CCE research has yet to delve into the specifics of handling these in teaching scenarios. Also, so far there is limited understanding of students' emotional predispositions concerning CCE (van Susteren & Al-Delaimy, 2020).

Objectives

This study offers detailed insight into the perspectives and affective dispositions on CCE of its major target group: secondary school students. We explored the perspectives of these students across three key dimensions:

1) students' self-reported experiences in disseminating CC information
2) students' perceived role of educational institutions in CCE and their current CCE efforts
3) students' affective dimensions towards prospective CCE initiatives

Research design and methodology

We explored the perspectives of Austrian secondary school students (n = 78, grade 12, four academic track schools, *MAge*: 15.9; SD = 0.98; 41f), conducting a paper-pencil survey comprising demographic information and six open questions derived from a literature review (Authors, 2022) organized into three categories: 1) multiplying CC information, 2) educational institutions' role in CCE, and 3) students' affective dispositions towards CCE. Students' responses were analysed using qualitative content analysis (Kuckartz & Rädiker, 2019; interrater reliability κ = .84).

Findings

Our findings reveal that students believe their previous CCE did not adequately address actions to combat CC. Nearly half of the students stated to feel inadequately prepared for being CCE multipliers. They attribute their concerns to a total lack of opportunities to experience CC specific learning activities. Students reported superficial information and little time dedicated to CCE, attributing this to a neglect of CCE's cross-curricular character. Students' affective dispositions towards future CCE can

be categorized into negative, positive, dismissive, and mixed feelings clusters (Fig. 1). The largest group holds only negative feelings, followed by those with mixed feelings. Students with solely positive feelings, dismissive attitudes, and those with no specific emotions are less present in our sample. Detailed analysis and examples of students' statements will be presented at ERIDOB.

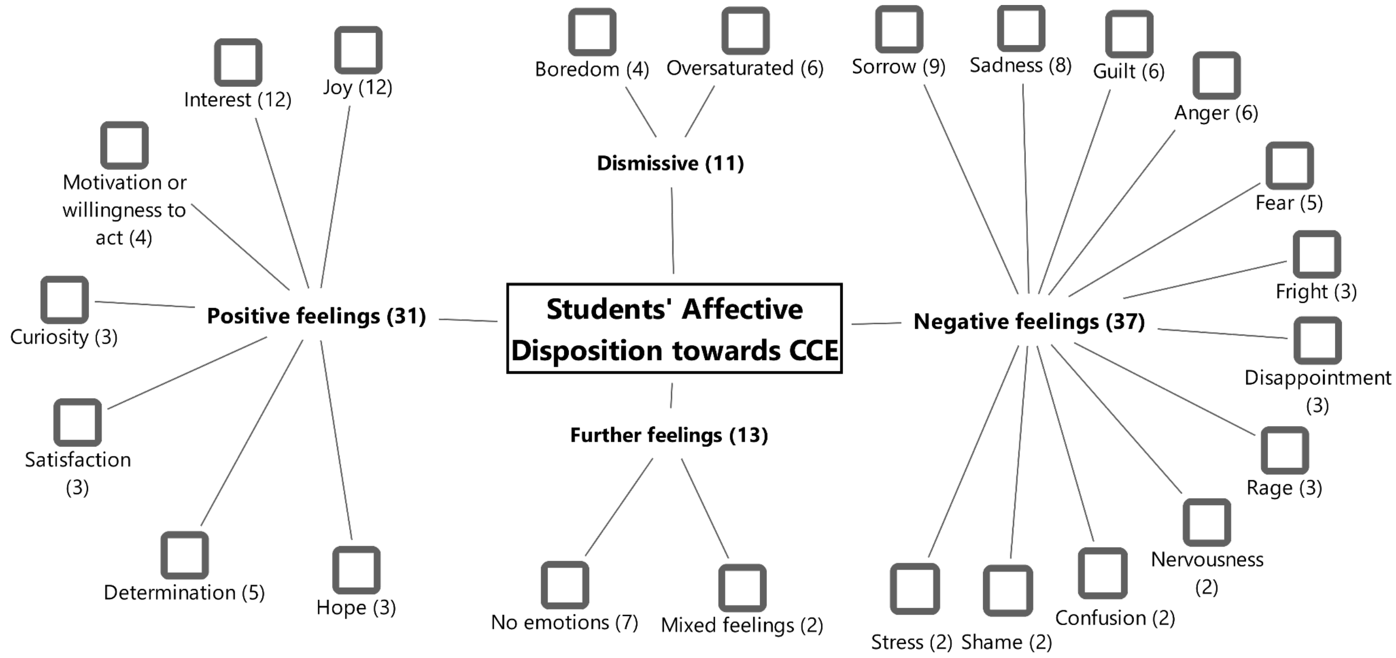

Fig. 1. Identified sub-categories (f ≥ 2), frequency of appearance (total numbers) and clusters in the category "Students' Affective Disposition towards CCE" (N = 78)

Conclusions

Our study examined the perspectives and emotions of a crucial target group of CCE: School students, who are among the most affected by climate change. Unlike most previous research, we treated students as experts regarding their CCE needs. Students' highly diverse and strongly emotional affective dispositions shown in this study present a unique challenge for CCE. Taking into account that mental health of young people worldwide is impacted by increasing CC consequences (Burke et al., 2018) and emotional experiences can significantly influence learners' engagement with CC, teachers need to actively address these and not inadvertently contribute to the feeling of disempowerment (Jones & Davison, 2021). Therefore, students need support from professionals in a trusting environment, where they can engage in mitigating CC and build climate resilience (Ho & Sew, 2017). Our findings reveal that CCE challenges extend to a systemic level within the educational system, often linked to educational policies and curricula. We recommend that CCE research addresses these challenges and focuses on designing, evaluating, and implementing CCE approaches that are responsive to students' needs. Additionally, there is a need to review and revise current educational frameworks and policies to better equip educators for learning environments that consider students' affective predispositions.

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Students'conception and conceptual reconstruction 3

Conceptualization about stream ecosystem in secundary education

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Theoretical background or rationale

Freshwater ecosystems have become one of the most threatened environments in the world due to human activities´ pressure (e.g. urbanisation and agriculture). Climate crisis is also expected to produce severe consequences, endangering the ecosystem services provided by these systems. As inland waters are a natural resource of great value (economic, cultural, aesthetic, scientific and educational), their conservation and management are in the interests of governments and people alike.

Rivers and streams are often understood as natural channels that flow into the sea, and the ecological perspective has historically been neglected. Thus, river management policies have been based on hydraulic engineering, leaving aside the hydroecological framework of these systems and, consequently, contributing to river degradation (BLINDED, 2020). However, the modern paradigm in river management is based on basin-level planning, ecosystem science and assessment (Hillman, 2009). In this new paradigm, public participation has also become a key element, as sustainable management policies and practices require community recognition and engagement, as well as training. In this sense, compulsory education can be key to addressing the degradation of rivers and other ecosystems and putting in place measures towards good ecological status. Indeed, by bringing scientific knowledge closer to citizens, students can be trained to actively participate in the transition towards a sustainable society.

In the achievement of science teaching objectives, models acquire great importance in science curricula and in students´ learning process. Educators incorporate these models into educational curricula (school model) adapting the level of conceptualisation to the cognitive level of each age group. Likewise, individual mental models are used to explain a certain phenomenon or idea. Therefore, the analysis of mental models provides insight into the conceptualizations about a particular phenomenon, which can help to understand the difficulties and conceptual errors that may exist on this topic (Oh and Oh, 2011). This can also allow teachers to design appropriate modelling sequences, in which the students' mental model approaches the most appropriate scientific model (Oliva, 2019).

As for the stream ecosystem model, few studies have addressed the subject. Analyses of students' models show that their usual conception does not reach the ecosystem level (Martínez Peña and Gil Quílez, 2014; Ladrera et al., 2020), and no studies have been found analyzing teachers´ mental models in relation to river ecosystems.

Key objectives:

i) To analyse the degree of development of the river ecosystem model of 4th year Secondary Education students (15-16 years old) and Secondary Education teachers in order to identify the learning demands necessary to get closer to the scientific model.

ii) To determine the level of knowledge about the ecosystem services provided by river ecosystems in both groups.

Research design and methodology:

In total 155 students and 46 teachers (with different specialisations) were asked to fill in an *ad hoc* designed questionnaire to define the stream ecosystem (open question) and list the ecosystem services provided by streams. The results of this questionnaire were qualitatively analysed. Open question was after analysed via phenomenographic approach (Han and Ellis*,* 2019). The ecosystem services listed were analysed on the basis of the proposal established by the Millennium Ecosystem Assessment (Alcamo et al., 2003), according to the following categories: provisioning, regulating, cultural or support services.

The study was carried out in several secondary schools in in a small Atlantic and very impacted catchment, and the study was conducted with the authorisation of each school's management team and the approval of the teaching staff. This study has the permission from the Ethics Committee on Humans (CEISH) of the University of the Basque Country (UPV/EHU) (CEISH/M10/2023/143).

Findings:
With regard to the description of the stream ecosystem, the phenomenographic analyses resulted in 4 caategories (Table 1). Most of the students' responses described streams as systems consisting of living elements and/or processes (C2, 30%), in which several also considered the abiotic elements (C1, 26%). Only 11% described the stream using a basin view (A and B). 10% described streams as water transporting systems (C3), and 19% could not give a description (D and E). Among teachers, 33% and 30% of the descriptions corresponded to C2 and C1 categories respectively. 30% described streams including a basin-wide view (A and B), and only 7% could not compose a description.

Regarding stream-related ecosystem services, the most frequently mentioned by students were those related to provisioning and supporting (82% and 61% respectively). Services related to regulation and culture were only mentioned in 15% and 13% of the answers respectively. Likewise provisioning and supporting services were most mentioned among teachers (72% each), and regulation and cultural services were mentioned in 41% and 30% of the answers respectively.

Table 1. *Phenomenographic categorization explaining the views expressed (categories C3 and D were only observed for students).*

	Category	Description
A	Basin level ecosystem	Stream ecosystem defined as an ecosystem located in the territory (landscape, basin…)
B	Basin level biosystem	Stream ecosystem defined as a biotic system located in the territory (landscape, basin…)
C1	Ecosystem	Stream ecosystem defined as a system composed by living and non-living elements and/or processes
C2	Biotic system	Stream ecosystem defined as a system composed by living elements and/or processes
C3	Abiotic system	Stream ecosystem defined as a system composed by abiotic elements and/or processes
D	Tautology	Repeats the information given in the statement without adding any new information
E	No answer	There is no answer, or has no relation with the question

Conclusions:
The conceptualization of the stream ecosystem rarely reaches the basin level, both among secondary school students and teachers. When the model reaches the ecosystem level, most of the time a list of elements is given without considering interactions.
Regarding the perception of the ecosystem services offered by streams, there is little knowledge of the main ecohydrological and hydroclimatic processes.

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What do you mean heterogeneity?
Assessing understanding during learning reveals each learners' unique progression 3

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INTRODUCTION

School goals in many societies include reducing the influence of social and gender inequality, integrating cultural differences and approaching specific learning disabilities as special needs but also special capabilities. However, many educators find heterogeneity difficult to manage, perceive diversity as a problem, and often refer to categories. We consider heterogeneity at the individual level and we postulate that each learner is best helped if guidance is informed by individual progression.
For guidance during learning, to improve learning designs, and for research about learning processes, evidence about learning progression is required, but relevant data are difficult to obtain. Since teachers cannot directly access students' understanding, assessment is based on what we observe students to produce (Bennett, 2011), either from instruments specifically produced in order to assess - or from informal data (productions, observations, oral interactions while learners perform tasks, …) (Mottier Lopez, 2015).

The relevance of assessment instruments depends on the decision they will help to take. Our goal here is to produce data - by measuring an expression of current student understanding - to help heterogeneous students towards the educational goals (formative, rather than certificative assessment) (Mottier-Lopez, 2015). We developed process variables and methods to capture heterogeneous learning paths, and the evolution of students' explanations quality all along the learning process. These were also used to measure the efficiency of features of the designs – for their improvement - and for research on learning processes and difficulties.
Assessment is crucial, but often overlooked in science education (Millar, 2013). Since the structure of knowledge in each discipline differs, specific methods are needed to assess qualities of biology explanations.

To explore their heuristic power and improve them, our instruments were successively applied to a large (over a million of words) data-set (time stamped answers of student productions recorded in a wiki), spanning multiple small cohorts of secondary high school students in a computer-supported collaborative learning design. This unusually fine-grained data was analyzed to produce evidence of individual progressions.

Mapping learning progress onto the reference learning goals had suggested in a previous study that students' understanding develops along heterogeneous individual paths. Progressions appeared as unsystematic steps filling a mosaic rather than linear, and seemed incoherent to experts during most of the learning process, until the learning goals were achieved ("full mosaic"). To search for patterns, a second study had computed across multiple cohorts a prevalence index (PI) revealing which items of the learning goals students mastered on average early (low PI) or late "slow-spots". A third study had shown that good inquiry questions appeared progressively out of vague initial questions and revealed when epistemic complexity (explanations rather than descriptions) appeared in inquiry cycles.

METHODS

In this fourth study the relevance of answers to the currently taught molecular biology paradigm was assessed all along learning process, across cohorts and heterogeneity of progressions was analyzed. To assess the quality of student's explanations, we elaborated a coding scale that measures the paradigmicity of answers as

1) explanations, 2) referring to molecular mechanisms 3) causal-objective. It produces Molecular (M), and Causal-Objective (CO) scores (from 0 to 2). The scale was adjusted by two coders until 82% intercoder agreement, then all was recoded by one researcher. This method was applied to the large data set of wiki traces mentioned. Groups of 3-4 students iteratively wrote their understanding in a shared document. Each group took responsibility for a subchapter (e.g., allergy, humoral immunity, cellular immunity, vaccination), building a common document on which all students relied to prepare for

exams.

As an example, we discuss here answers to an inquiry question: "What are the mechanisms that produce allergy?" in 9 cohorts. For each cohort of 12-16 students, we selected 4 versions of student text and coded M- CO scores for each of the 47 items in the map: 1690 versions were analyzed. We computed averages in each cohort. Low-scores reflect items for which students' answers took more time to express good paradigmicity.

We analyzed M-CO scores for: 1) Variability and trends across different item averages, 2) Variability of each item across cohorts, 3) Progression profiles within cohorts for each item, 4) Correlation between M and CO scores.

RESULTS

To illustrate how scores can be used to reveal areas where students' answers show earlier or later evidence of understanding, the average M (Fig. 1) and CO scores (not shown) for each item were mapped onto the reference knowledge map.

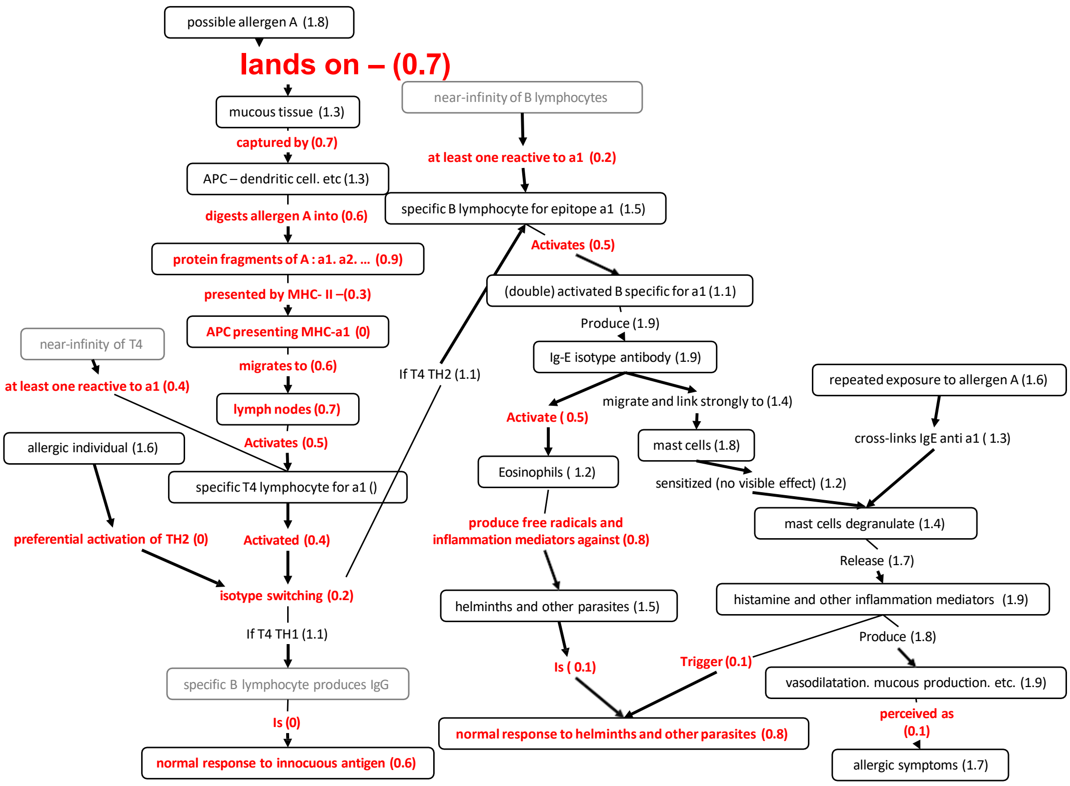

Figure 1 Consolidated average scores for each item of the reference knowledge map. Scores in parenthesis next to the item label. Low scores (<1) in bold and red.

Our results revealed the heterogeneity of students' explanation quality for each item of the learning goals, and some intriguing areas where progression seemed very heterogeneous.

DISCUSSION

The discussion focuses on the heuristic power of these assessment instruments: how they can produce well- needed evidence to inform guidance of students *during* learning, for formative feed-back, and to optimize designs. 5

Educational implications include the need to focus on students' awareness of knowledge gaps and guidance to fill them, rather than slide order or lecture sequence. Study 3 highlights question elaboration as a process that needs to be supported, and how in inquiry designs many students benefit from their full potential mostly towards the end of the cycle – questioning short IBL interventions. Study 2 and 4 produced evidence and criteria to give helpful formative assessment to heterogeneous learners when it is most efficient (early and along learning). They also empirically identified concepts and the nature of explanations that require special attention for guidance. This unusually fine-grained evidence can help optimize design elements, and opens venues for research into the causes for slow-spots, and heterogeneity management will be discussed.

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Greek secondary school students' teleology and essentialism conceptions about genes

6

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THEORETICAL BACKGROUND

Research has documented students' misconceptions about the nature of the genetic material, its roles, or those related to genetic determinism, the idea that single genes invariably determine traits. At the same time, conceptual development research suggests that students' conceptions are often influenced by deep human intuitions, such as design teleology and psychological essentialism. Design teleology is the idea that a trait exists for a purpose, being the outcome of design. The notions of design and purpose are of interest as they could enhance the erroneous idea of "genes for" traits, in the sense that genes exist for an intended use or purpose. For instance, in a study it was shown that essentialist and teleological conceptions about inheritance are contrasting: traits with some function are either more heritable and less modifiable (essentialist stance) or less heritable and more modifiable (purpose-based stance) (Ware & Gelman, 2014). Psychological essentialism is the intuition that organisms have essences, which are fixed. Recently, it has been suggested that essentialism also has a strong impact on people's understanding of heredity, as it may lead people to view genetically influenced traits as determined and immutable (Heine et al., 2017). It may therefore be the case that students' misconceptions about heredity may be caused by intuitive thinking based on teleology or essentialism.

RESEARCH DESIGN AND KEY OBJECTIVES

The main goal of the study was to investigate Greek secondary school students' conceptions about genes, and their relations to teleology and essentialism. Following the work of Author 1 and colleagues (2020, 2023), we administered the questionnaire used in those studies to a sample of 1329 students from 21 secondary schools (students' ages 12-17) in Greece, between February and April 2021. The responses were collected using an electronic questionnaire. The researchers contacted the teachers who taught biology courses at secondary schools, and informed them about the rationale and the goals of the research. Teachers participated after receiving permission from their school principal (in two cases, the principals did not give their permission to conduct the study). Those teachers who received permission administered the questionnaire to their students in an electronic form at the time of their choice, in a school room that had the appropriate equipment. The original questionnaire was translated and back-translated between English and Greek, and was used in a pilot study with 70 students.

Our aim was to provide answers to the two following research questions:

- RQ1. *Do Greek secondary school students exhibit teleology or essentialism conceptions about genes?*
- RQ2. *Are there any differences in teleology or essentialism about genes among Greek secondary students with respect to age?*

METHODOLOGY

For each of the three subdimensions of the questionnaire (teleology about genes, essentialism about the homogeneity of genes, and essentialism about their fixity), percentages of students' answers are displayed in the figures that follow - note that missing data or "I don't know" answers (on average 11%) are not shown. We distinguished among three levels of teleology, from the strongest to the lowest: design teleology, need-based teleology, and natural teleology (natural selection); as well as among three levels of essentialism, from the strongest to the lowest: psychological essentialism, moderate essentialism, and weak essentialism. We conducted an analysis of variance (ANOVA) to investigate the effect of age on students' teleology or essentialism intuition. All calculations were made with the statistical R software (*R Core Team. http://www.R-project.org/*, 2014).

FINDINGS

Teleology

As shown in Figure 1, the overall proportion of misconceptions (design and need-based teleology conceptions considered together) varied across the different ages between 73% (15 years old) and 62% (17 years old), and the impact of age was found significant ($F(1,1327)=28.2$, $p<0.01$).

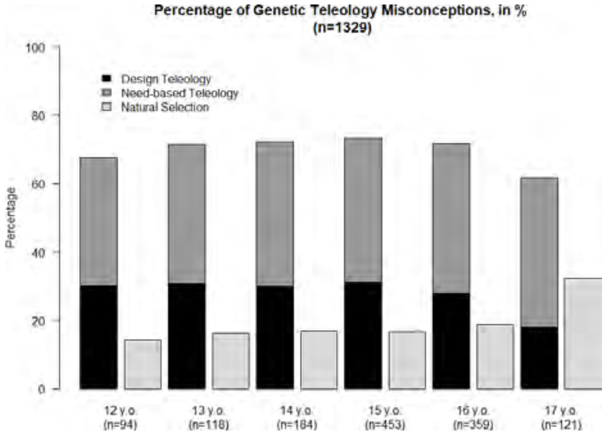

Fig 1 Average students' answers to the teleology items, by age. The misconceptions "design teleology" and "need-based teleology" (respectively in black and dark grey) are stacked and are contrasted with the correct conception "natural selection" (in light grey).

Essentialism

As shown in Figures 2 (left), the overall proportion of genetic essentialism – homogeneity misconceptions (psychological and moderate essentialism conceptions considered together) decreased across the different ages from 54% (youngest students, 12 years old) to 38% (oldest students, 17 years old), and the impact of age was found significant ($F(1,1327)=26.7$, $p<0.01$). Besides, on Figure 2 (right), the overall proportion of genetic essentialism – fixity decreased across the different ages from 37% (youngest students, 12 years old) to 19% (oldest students, 17 years old), and the impact of age was also found significant ($F(1,1327)=37.3$, $p<0.01$).

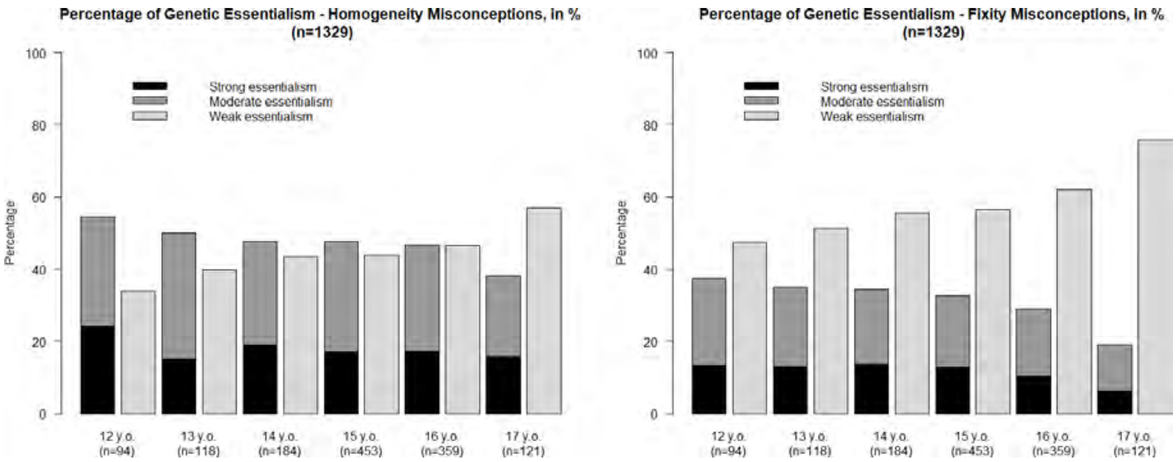

Fig 2 Average students' answers to the essentialism items about the homogeneity of genes (left) and fixity of genes (right), by age. The misconceptions "psychological essentialism" and "moderate essentialism" (respectively in black and dark grey) are stacked and are contrasted with the correct one "weak essentialism" (in light grey).

CONCLUSIONS

With respect to RQ1, we found that Greek secondary school students exhibited teleology and essentialism conceptions about genes, with the former being more prevalent than the latter. Design teleology and need-based teleology conceptions were present in more than 60% of students' answers across all grade levels, with the preconceptions being quite less prevalent among the oldest students. Essentialist conceptions related to fixity (>30% overall) were less prevalent than those related to homogeneity (>45% overall). For RQ2, there were significant differences with respect to age for all three intuitions considered, which might be attributed to the impact of schooling as overall misconceptions were less prevalent in older students than in younger ones.

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New approaches to NOS, transfer, philosophy, complexity

A family resemblance approach to biology education research: teachers' conceptions on transfer

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Theoretical background or rationale

To bridge still existing gaps between research and practice communities, it is imperative that both sectors initiate steps towards mutual understanding to foster transfer of research results (Farley-Ripple et al., 2018). This entails not only including perspectives from practitioners into research but also equipping practitioners with a sophisticated understanding of research. While some studies have attempted to address this issue by enhancing teachers' research competencies through their involvement in research projects (e.g., Yosief et al., 2022), they have predominantly concentrated on cognitive aspects, such as methods and knowledge, often overlooking the social-institutional dimensions of the research-practice nexus. This may hinder transfer, which is represents the knowledge exchange between research and practice. The present study seeks to fill this research gap by applying the family resemblance approach (FRA), a model established in nature of science research, to the domain of biology education.

Key objectives:

In the last decades, several theories emerged to explain the nature of science, including consensual or whole science approaches. While these approaches often focused on cognitive dimensions such as methods, the FRA explicitly includes social-institutional dimensions (Cheung & Erduran, 2022). Particularly categories such as social certification and dissemination offer opportunities for understanding transfer, as knowledge about teachers' conceptions on this would enable for the investigation of factors relevant to the uptake of science educational results (Table 1). Therefore, the present paper addresses the central research question: Which conceptions do biology teachers hold for the nature of biology education research in the category social certification and dissemination?

Table 1. Overview of the selected category from the FRA (Erduran et al., 2019) and relating interview questions.

Category	Description	Example questions relating to transfer
Social certification and dissemination	Social processes in relation to the certification and dissemination such as evaluation by peers or journal articles	What do you think about the evaluation of results from biology education research? How are results from biology education transferred? Are you discussing biology education research with your colleagues?

Research design and methodology:

To understand teachers' conceptions, we interviewed 11 biology teachers from Germany. As no prior studies existed, we decided for a qualitative grounded theory approach and sampled the teachers based on opportunity. Table 1 shows further details about questions asked in the interviews. The data was coded using multiple steps. First, the data was coded for the 11 general categories of the FRA. In a second step, the codes for the category social certification and dissemination have been coded inductively.

Findings:

Figure 1 gives an overview of the general distribution of codings. The number of codings illustrate how also social values and social organization were highly coded categories.

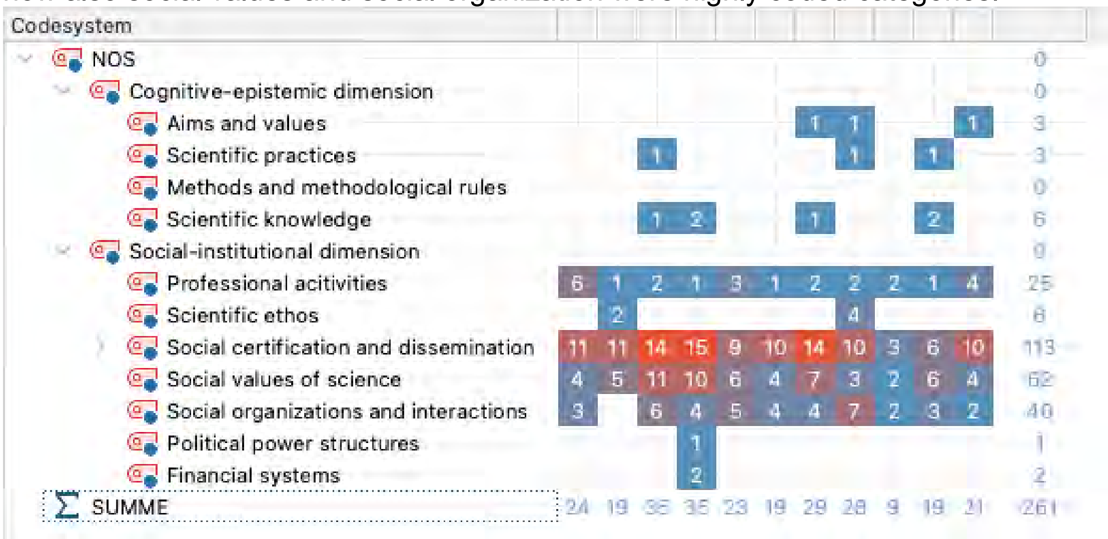

Figure 1. Screenshot from MAXQDA illustrating the codes assigned to the FRA-categories.

Table 2 displays the categories that were inductively derived from the data. Several channels for dissemination were identified. In addition to traditional media such as practice journals and books, numerous teachers highlighted digital platforms, including newsletters and websites, as valuable resources. However, despite these avenues, the majority of teachers reported a lack of sufficient time to stay abreast of new findings. Pertaining to certification, some educators noted that they engage in discussions about recent results with their colleagues, citing recency and specificity as key criteria.

Table 2. Identified categories regarding social certification and dissemination.

(Sub-)categories (Code)	Description	Implication
Dissemination (1)		-
Sources (1a)	Sources of new results	-
- Colleagues (1aa)	Colleagues distribute new results	Innovative colleagues may foster transfer
- Research projects (1ab)	Participating in research projects	Research projects can foster transfer
- General media (1ac)	General media outlets (e.g., newspaper)	Only few topics are discussed in large media
- Books (1ad)	Books on biology education	Books are a more reliable and slow source
- Digital opportunities (1ae)	Digital outlets such as newsletters	Newsletters/social media can be used
- Teacher training (1af)	Teacher training for specific topics	Teacher training for S|E|H should be done
- (Practice) journals (1ag)	Journals about research and practice	Journals as a slow source
Missing time (1b)	Not enough time for looking for new results	Teachers need time for development
Teacher age (1c)	Dissemination may depend on age	Age-related offers could be needed
Certification (2)		-
Sharing experiences (2a)	Experiences about pedagogy are exchanged	Direct experiences are more reliable
Recency (2b)	Results have to be recent	Results need to be recent
Situation-specific (2c)	Results have to be subject-specific	Subject-specific results needed
Critical perspective (2d)	Critical perspectives on viability	Practice has specific needs
No discussion of results (2e)	Explicit disagreement of discussions	Discussion is not always possible

Conclusions:
Given the qualitative nature of the results, the study allows for a diverse and in-depth look into teachers' conceptions on social dissemination and certification of biology education research, including new insights into problems related to transfer. More explicitly, the results illustrate conceptions which are the foundations for teachers' decisions for the uptake of biology education research results into practice. Further may give a quantitative insight into how these conceptions may hinder transfer, for example in professional development situations. Particularly, possible interrelations between social certification and the social organization and values may be interesting, as they offer insight into value-related differences between research and school practice.

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Biology-specific nature of science concepts. An interview study with scientists

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Theoretical background

Fostering an adequate understanding of the nature of science (NOS) contributes to the development of students' scientific literacy (Lederman & Lederman, 2014). Studies indicate that students' NOS understanding differs depending on the reference discipline (e.g., biology, chemistry, physics). For example, students show a less adequate understanding of the nature of biological models compared to the nature of chemical or physical models which may be explained by differences in corresponding learning approaches of the respective subjects (Authors, 2015). Thus, discipline-specific NOS aspects should be considered in science education (Schizas et al., 2016).
Different sciences share similarities, but also differ in certain aspects. Biological research examines living systems whose characteristics are theoretically described (Tab. 1). Features like considering the individuality of living research objects during the error analysis of biological experiments (Bässler, 1991) highlight the unique nature of biological research. Consequently, it appears plausible to associate the characteristics of biological research objects with biology-specific NOS content.

Tab. 1. Characteristics of living systems as research objects described in the literature (e.g., Bässler, 1991; Mayr, 1991; Vollmer, 1995)

Characteristics of living systems as research objects	Description
Individuality	Systems are unique. They are each variable and differ from other entities of the same group.
Aliveness	Systems do not last over time but are finite. They are irreversible and subject to the unique directions of time. Entities are sensitive to pain.
Openness	Systems dynamically interact with other entities of their own and other groups (environment).
Emergent properties	Systems possess emergent properties that their individual components lack in isolation. These properties manifest only through interactions among the components.
Development	Systems change over time.
Diversity	Systems can be arranged into distinct groups. Overall, several different groups can be described.

With the Family Resemblance Approach (FRA) to NOS, different scientific disciplines can be theoretically described for science education purposes (Authors, 2022). In this regard, Kampourakis (2016) describes three types of NOS aspects pertinent for science education: cross-disciplinary NOS aspects, cross-disciplinary NOS aspects with discipline-specific characteristics, and discipline-specific NOS aspects.

Gaining insights into the practices of scientists can profitably contribute to the development of theoretical conceptualizations for science education (Schwartz, 2012) such as the FRA. These insights can elucidate the implications of research features stemming from the unique characteristics of their research objects. However, it remains unclear which biology-specific aspects concerning NOS are deemed relevant by practising scientists. Based on the characteristics of biological research objects and FRA categories biology-specific NOS concepts can be described.

Key objective

As it is promising to investigate the perspectives of scientists as experts of their scientific discipline (Schwartz, 2012), the research aim of this study is to describe biology-specific NOS concepts grounded in authentic scientific practices. The research question is: Which biology- specific NOS concepts can be described through insights from practicing scientists based on FRA categories?

Research design

In this study, 29 semi-structured interviews were conducted with biologists (*n* = 6), chemists (*n* = 8), physicists (*n* = 10), and–as an outside perspective–philosophers of science (*n* = 5). The scientists were asked to give their estimations on the following FRA categories (Authors, 2022): practices (observing, experimenting, comparing, modelling), methodological rules (use of controls, choice of research object, choice of sample size), models as a form of knowledge, scientific ethos.

The recorded interviews (M: 40:16 min, SD: 12:14 min) were transcribed and subsequently edited. Using a structuring qualitative content analysis, statements from the interviews were deductively assigned to the FRA categories and the discipline to which a statement refers (e.g., biology). The comparison of a first and second coding of three interview transcripts revealed an almost perfect intercoder agreement (κ = .93).

Next, biology-specific NOS concepts were explicated based on the statements which were assigned to the FRA categories and the content of the statements. They were assigned to the characteristics of biological research objects (Tab. 1). The structuring resulted from a mutual comparison of the literature (e.g., Mayr, 1991) and the interview statements. The comparison of a first and second coding of two interview transcripts revealed substantial and almost perfect intercoder agreements (κ = .69; κ = .89).

Findings

Based on the interview statements, 15 biology-specific NOS concepts were explicated and assigned to the characteristics of biological research objects (Tab. 1). Table 2 exemplarily shows NOS concepts assigned to Individuality.

Tab. 2: Biology-specific NOS concepts assigned to Individuality

Biology-specific NOS concept	Description	Statement from the interviews
	The individuality of biological research requires …	
Individuality requires model organisms	… the use of model organisms, e.g., in experiments or in the choice of research objects.	As a strategy [the use of model organisms] is the biological version of the experimental approach: you have to control the variability and for that you first have to get rid of it. Then, in a second step, you can recover it. (Philosopher 29,7)
Individuality requires big sample sizes	… big sample sizes, e.g., in experiments.	When working with primary cells, the special character of experimentation stemming from the experimental objects is the individual effect of the donor's cells. It's important to study a certain sample size (several donors). (Biologist 01,2)
Individuality requires reproducible conditions	… reproducible conditions, e.g., in experiments.	Every biological system displays variability. There is always something unpredictable depending on how the organism reacts to environmental conditions. We, as a molecular biology and genetics laboratory, depend on stable reproducible conditions. (Biologist 03,2)
Individuality requires statistical analyses	… statistical analyses, e.g., in reasoning processes.	We would do statistical analyses to conclude whether there is a difference in the framework of statistical ineffectiveness or whether it is just variability that we see there. (Biologist 02,5)

Striking findings emerged in the identification of corresponding FRA categories within the NOS concepts (Tab. 3).

Tab. 3: Assignment of biology-specific NOS concepts to corresponding FRA categories grouped into characteristics of biological research objects

Characteristics of biological research objects Biology-specific NOS concepts	**Practices**	**Methodo-logical rules**	**Knowledge (Models)**	**Scientific ethos**
Individuality				
Model organisms	X	X	X	X
Big sample sizes	X	X		
Reproducible conditions	X	X		
Statistical analyses	X			
Aliveness				
Housing conditions for validity	X	X		
Sample size determination processes	X	X		X
Compliance with legal regulations	X			X
Openness				
Specific controls	X	X		
Interactions between organisational levels	X	X		
Reproducible conditions	X	X		
Emergent properties				
Interactions between organisational levels	X	X		
Model organisms	X	X	X	
Development				
Specific selection criteria of model organisms	X	X	X	
Statistical analyses	X	X		
Diversity				
Variety of practices	X			

Conclusions

The analysis of statements by scientists concerning the characteristics of research objects, when interpreted through the FRA framework, indicates that research objects play a crucial role in describing a biology-specific NOS. Such NOS concepts hold potential for integration in biology education. Notably, the characteristics of research objects have not yet been explicitly described in existing NOS frameworks (e.g., FRA; see Authors, 2022). Based on our findings we propose the introduction of a novel and pivotal FRA category. At the conference, we will further elaborate on ways to incorporate reflections on NOS in educational settings, drawing from statements by practicing scientists. We will also present strategies to establish meaningful connections between the characteristics of biological research objects and the specificities of biological research in the context of science education.

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"All of biology consists of complex systems": How experts conceptualize complexity in biology education.

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Theoretical background

In recent years the science education curriculum has become increasingly focused on the study of complex systems. This is unsurprising considering the nature of the world students live in today- one increasingly governed by complex systems that are dynamic, self-organizing, and continually adapting. Complex systems are a fundamental aspect of all the biological sciences, be they processes that take place inside the organism at various levels (molecular and cellular levels up to the organ and system levels), interactions between different organisms, or interactions between organisms and their environment (Hmelo-Silver et al., 2007). Since complex systems are ubiquitous in biology, understanding biological phenomena necessitates proficiency in systems thinking (Gilissen, et al., 2020; Verhoeff et al., 2018). Systems thinking is a way to understand, explain and interpret complex and dynamic systems. It is a learning strategy that explicitly considers system characteristics in trying to understand and predict natural phenomena (Verhoeff et al., 2018).

Key objectives:

To explore the nuanced understandings that biologists, science education researchers, and leading biology teachers have regarding the conceptualization of complex systems in the context of ecology and comparative physiology.

Research design and methodology:

The first phase involved an interdisciplinary workshop that included experts from three groups: Senior academic staff in the fields of ecology and comparative physiology, senior academic staff in the field of science education, and leading biology teachers. The workshop presented the basic ideas of complexity in science education. The participants were divided into four groups which included representatives from each field of expertise aiming at exploring and presenting phenomena that have potential to advance biology student's systems thinking in the context of ecology and comparative physiology.
The second phase consisted of in-depth reflective individual semi-structured interviews with 17 participants aiming at conceptualization of the workshop outcomes in order to draw upon the scientific content relevant to the phenomena that were presented in the workshop, and the related design elements and pedagogical approach. The interviews were conducted over zoom and took between 30 minutes to an hour.

Findings:

Four key biological phenomena—motion, animal migration, seasonal reproduction, and oxygen and homeostasis—emerged from the workshop as focal points for enriching biology curricula. These phenomena offer avenues for deeper systems-level thinking. For the sake of brevity, we will discuss only one of these phenomena in detail:

Animal migration offers its own unique complexities. According to SE1, a PhD in science education who presented her groups insights: "Migration stems from an energetic requirement," addressing the system characteristics of "input, output, and boundaries." This is a pertinent subject for teaching complex systems because it allows for the use of inquiry practices, outdoor learning, and field trips, all of which can "make the learning experience more meaningful for students". The dynamic and cyclical nature of migration also serves as a robust example for teaching system characteristics such as dynamics, enhancing its educational value, and is relevant for all levels of organization.

One of the salient findings of the interviews was the diversity of perspectives among the different groups of participants. Particularly notable was the emphasis that biologists placed on interdisciplinary connections. Life Scientist 1 (LS1), a senior lecturer experienced in teaching undergraduate biology students, articulated this point by referring to high school students: "Biology is maybe the only scientific subject that students are exposed to in the best-case scenario. In the worst case, it is for those who are not suitable for other disciplines, which means that the interactions of biology with physics, or for example with engineering, do not exist at all… Modern biology is such that it cannot do without these fields almost at all." This statement

underscores the critical gap in interdisciplinary education, particularly between biology and fields like physics and engineering, a gap that other biologists also acknowledge.
The ubiquitous necessity of systems thinking was also reflected in the interviews. Science Education Researcher 6 (SE6) stressed that, "All of biology consists of complex systems. There is nothing in biology that is not a complex system." This viewpoint serves as a linchpin, highlighting the imperative of systems thinking in biology education. It functions not just as an academic tool but also as a lens through which to view the interconnectedness of various biological phenomena, which is also expressed by teacher 4 (T4), who wished that each topic in biology teaching was "spread more broadly to understand the contexts." Other emergent themes delve into specific pedagogical strategies essential for understanding complex biological phenomena. Science Education Researcher 1 (SE1) highlighted the critical role of modeling, noting, "Models are a wonderful way to put things together - take all the knowledge I have gained and now try to put them together and understand how they work together."

Conclusions:
The findings indicate that participating biologists, science education researchers, and biology teachers view that complex systems lie at the very heart of biology education. They highlight the importance of engaging students with complexity and system’s characteristics. Four main phenomena emerged as especially suitable for studying complex systems in biology. Our study also identified a gap between the perceptions of biologists regarding what is necessary in biology education and the current curriculum. These findings offer a basis for various recommendations regarding which biological phenomena offer a potentially fruitful basis for the learning of complexity in biology and various pedagogical approaches that can be instrumental in fostering students’ system thinking.

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Building consensus on the elements of philosophy of biology to inform science instruction

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This is not a presentation designed to share the results of research. Rather, this presentation is designed to involve those in attendance (experts in biology pedagogy) with the important task of discussing a few proposed elements of the philosophy of biology (PoB) that might be appropriate for the inclusion in pre-university science classes. In doing this, we begin the process of consensus building moving toward a list of such elements of the philosophy of biology that, as a group, we might recommend inform plans for science teaching and learning.

Key objectives:
There are three key objectives of this presentation; 1) to share with the attendees a list of proposed elements of the philosophy of biology that might be recommended for inclusion in pre-university science teaching plans and 2) to elicit comments from the group of attendees regarding the appropriateness of the elements of PoB presented and 3) gain additional insights from the attendees regarding PoB elements not mentioned.

Research design and methodology: (Again, this is not a presentation of research, please contact proposer with any questions or suggestions from the scientific committee about the goals of this presentation). I will use this space to provide some background for the proposed presentation.

For decades science educators have agreed that elements of the philosophy of science should be included in science instruction to provide a foundation for students focusing on “how science works.” While there has been debate about exactly what those elements should be and at what grade/age level they should be featured in the curriculum, there is little argument about the value of aspects of the philosophy (or nature) of science for those learning both the traditional content of science and developing an accurate understanding of how science functions. As such, the philosophy or nature of science (NOS) for science instruction is reasonably well defined by consulting either the so-called “consensus view,” the emerging family resemblance (FRA) approach or some combination thereof.

However, even with some shared view of the NOS elements to be included in plans for science teaching and learning, there is some consideration for how/if those key ideas function at the level of the individual science disciplines such as biology -- the focus of the presentation here. So, in moving from science in general to the realm of the subdiscipline of biology, we encounter the philosophy (or nature) of biology as part of philosophy of science related to issues in how scientists study living systems. There seems to be some agreement on the main elements of the philosophy of biology with an educational component as seen in the work of Kampourakis (2013) for instance. However, it is not yet possible to visualize a “list” of elements that could be included in plans for science learning. So, I would argue that the task now is to examine the elements of general NOS and consider how those elements or tenets function in biology while discussing the unique issues (such as the philosophical role of evolution) that pertain exclusively to the life sciences.

Findings: (Again, this is not a research presentation)
Therefore, the first part of the session will be a presentation of general NOS elements within the special domain of biology and will include elements such as the application of the law/theory distinction (with special focus on cell “theory” and the issues of generalizability and universality of such principles), the issue of reductionism/holism in biology, the philosophical role of the chosen unit of study (i.e., species to ecosystems) in the life sciences, and how general scientific methodology applies to biology.

Next, we will turn our attention to emerging questions/issues to refine and expand the elements already mentioned to accommodate the ever-growing complexities of the biological science and related philosophical implications. These issues include but are not limited to the extended evolutionary synthesis, levels of selection, ethical issues in biology, the nature of causation in the life sciences, a more expansive definition of life that includes holobionts (host organisms and their associated microbiomes), synthetic “life”, biosemiotics (information processing in living systems) and other issues at the forefront of the philosophy of biology.

Conclusions:

The philosophy of biology is an interesting, diverse, and evolving field with some ideas and concepts that enjoys a degree of consensus. However, much work remains in translating both the pedagogical contribution relative to general NOS and the emerging work in PoB to school settings. There can be no better forum to have this conversation than with the experts assembled at ERIDOB. The goal of this presentation is to start a conversation about the nature of biology for school science purposes, certainly not to conclude the discussion. The presenter will share some ideas about how we might best continue the conversation after this presentation and will invite interested attendees to participate in a variety of ways ranging from a potential Delphi study to a future symposium on this topic designed to maintain the focus on defining a practical and achievable “school” version of the philosophy of biology.

Note: Should the scientific committee find this topic of interest, the presenter would look forward to a conversation about how to modify, focus and/or extend this discussion at ERIDOB. For instance, could this become a plenary session that might engage all attendees with time available to begin the process of reaching some conclusions?

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Teaching with digital media

Technology enhanced teaching: dissecting the use of 3d anatomy apps for animal specimen examination

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Theoretical background and rationale

Mobile devices are increasingly being used in biology teaching, enabling inquiry activities to be carried out using digital tools (Elmali, 2022). Anatomy education typically uses three- dimensional (3D) human body anatomy apps, which have already been proven effective in higher education for learning anatomical structures (Chakraborty & Cooperstein, 2018). These apps provide a deeper understanding of the learning content, and students find the combination of virtual and real dissection helpful in reinforcing their learning (e.g., Lewis et al., 2014, Park et al., 2019). While dissecting animal specimens can advance learning about human biology in schools, only a few virtual alternatives have been investigated thoroughly in the context of biology teacher education (Elmali, 2022).

Key objectives:

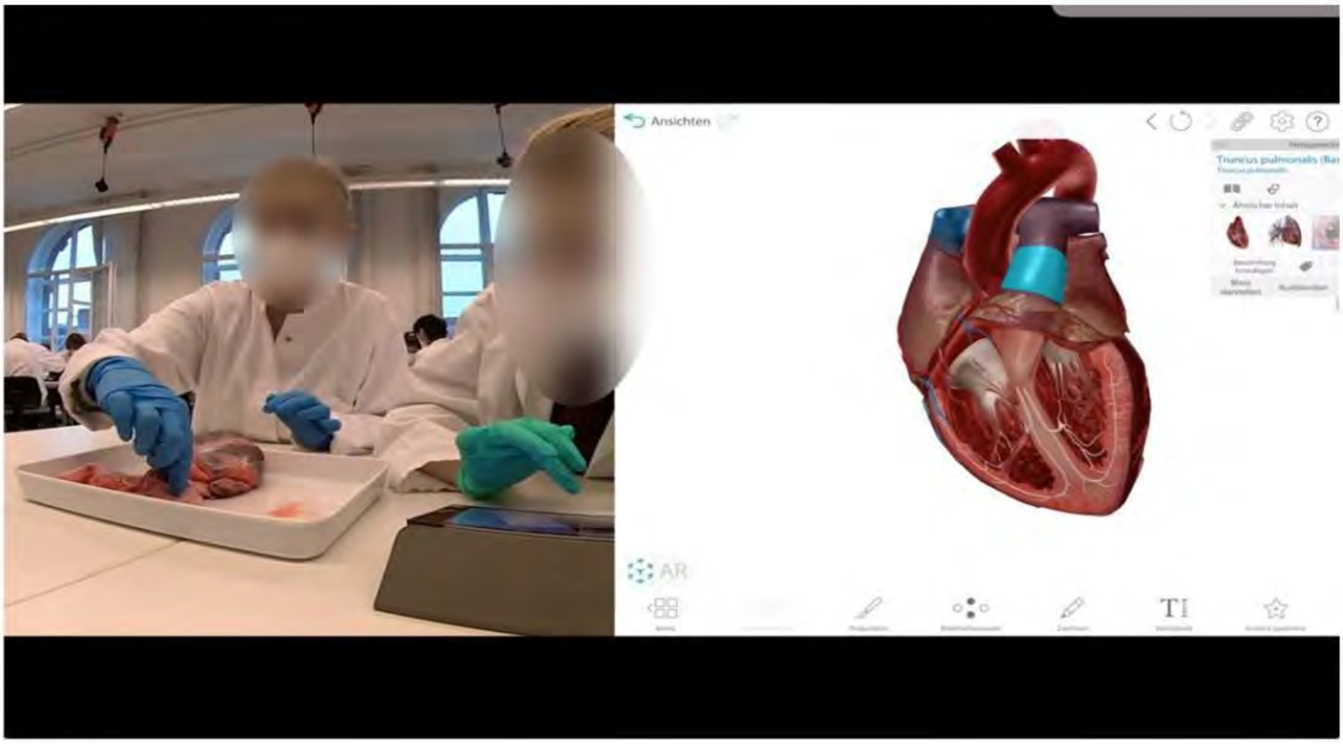
We combined traditional animal specimen dissection in biology teaching with 3D human anatomy apps. Most studies used questionnaires to test learning achievements, but self-reported data made it difficult to draw independent conclusions about usage patterns. We aim to identify how pre-service teachers use 3D anatomy apps during specimen dissection in higher education to identify behavioural patterns that could help or hinder learning about human biology with digital tools and support the development of corresponding scaffolds.

Research design and methodology:

Applying a cross-sectional design, we videotaped pre-service biology teachers when dissecting animal specimens in a university course. The dissection was advanced by the facultative use of 3D human anatomy app models on tablet computers. For data analysis, we developed a video- coding guide. A total of 1718 codes were assigned to 13 coded videos (total length=679.14 min; M=52.24 min; SD=11.45 min, see Figure 1). Six videos were used for pig eye dissection and seven were for pig heart dissection. Two raters applied a two-step coding process (IRR: κ =.76, substantial agreement). First, the videos were coded according to their on- and off-topic usage behaviours. Four codes refer to on-topic aspects: Exclusive Use of Original (EUO), Exclusive Use of App (EUA), Simultaneous Use of App and Original (SUAO), and Nonsense behaviour (NSB), such as students rotate the 3D app-model without having a visual focus on the tablet. Two categories refer to off-topic aspects: Technical Error (TE) and No Usage of the App or Original (NUAO), such as students preparing the workplace. In the second step, open-coding for the categories SUAO and EUA was performed to describe app usage in more detail using tree maps. These plots display hierarchically structured data in relation to the frequency of the codes applied. For this purpose, the category EUA was subdivided into EUA-1 (content exploration) and EUA-2 (technological exploration). The category SUOA was subdivided into SUOA-1 (establishing a relationship between app and original specimen) and (interactive comparison between app and original specimen).

Figure 1

Split-Screen Video showing students recordings of dissecting animal specimen (left) and the tablet screen (right) displaying the simultaneous use of the anatomy app.



Findings:

Regarding the main categories (see Figure 2, next page), 63% of the codes have been assigned to EUO, indicating that students have worked solely with the original specimen for most of the recorded time. This was followed by the SUAO category, with 11% of the codes assigned. EUA has been assigned a total of 6% of the codes. One percent of the codes was assigned to the NSB category. The off-topic categories NUAO and TE accounted for 17% and 3% of the assigned codes, respectively, indicating that most of the time was spent on the task.

Tree maps (see Figure 3) allowed for a more detailed analysis of the usage behaviour for the EUA and SUAO categories. A comparison of the two dissections shows that SUAO-1 and SUAO-2 were equally important in both cases. For SUAO-1, students' targeted search for structures was larger than the planning of dissection steps both times. For SUAO-2, a reversal can be seen. While in the eye dissection aligning the 3D app model with the original specimen accounted for the majority of the time, in the heart dissection, the structural position comparison was larger, indicating that the students performed positional determinations of structures much more frequently.

Figure 2

Distrubution of assigned main codes in comparisonfor eye and heart dissection

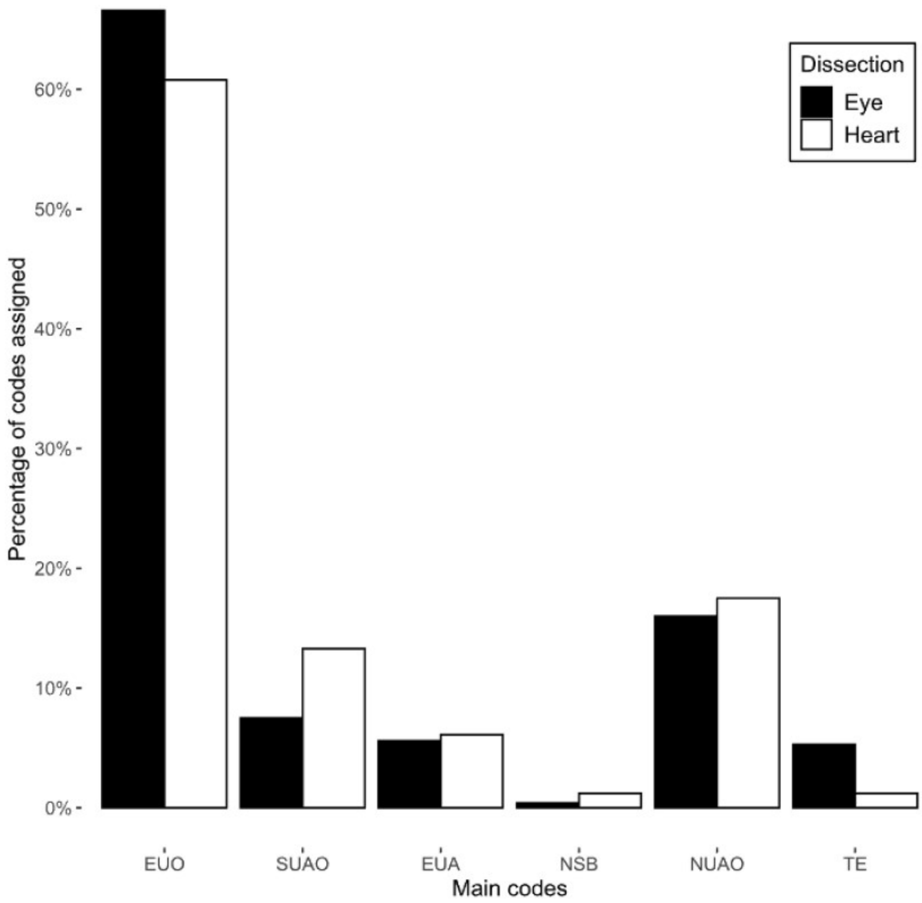
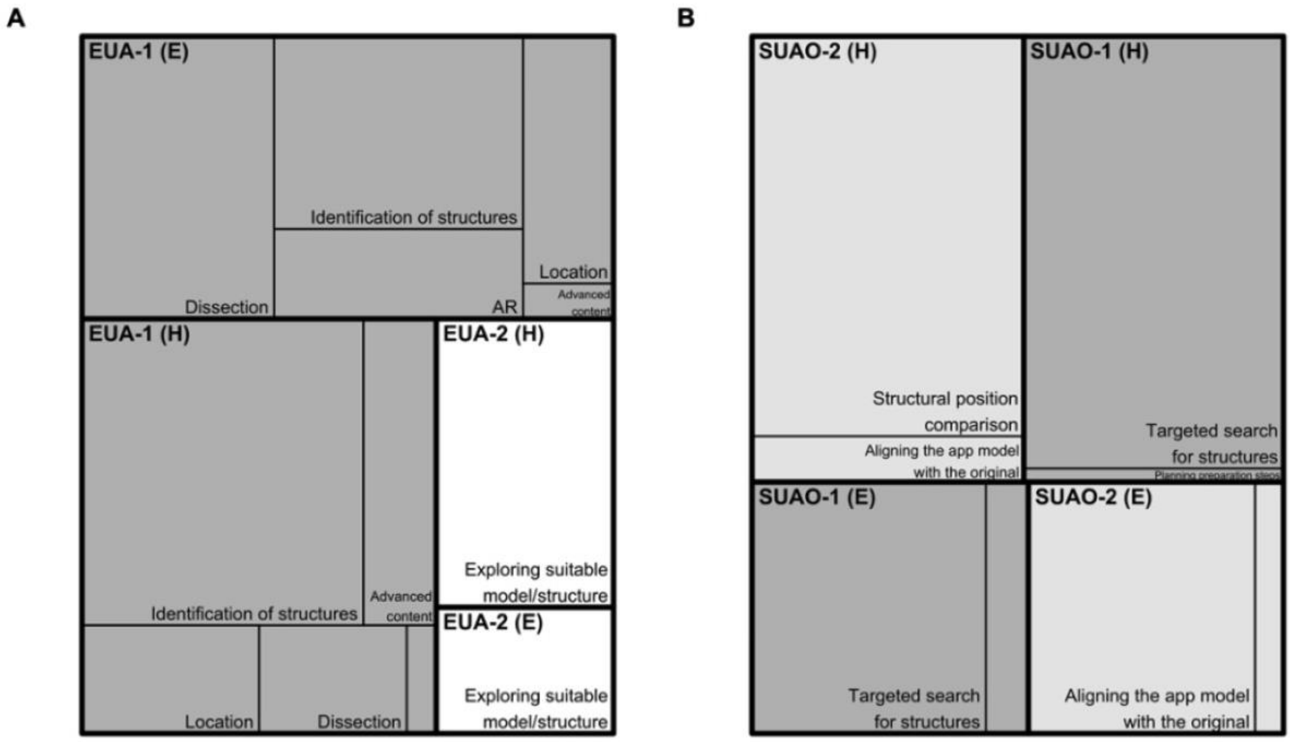


Figure 3

Tree map of EUA subcategories (EUA-1 content exploration and EUA-2 technological exploration) and SUAO subcategories (SUA0-1 establishing a relationship between app and original specimen) and (SUA0-2 interactive comparison between app and original specimen) in comparison over eye and heart dissection



Note. E = eye dissection, H = heart dissection.

Conclusions:

The study's primary findings were that the simultaneous use of app and original accounted for a substantial proportion of student behaviour. This suggests that the app was used in a supportive and targeted manner during the dissection of animal specimens. These results align with previous research which has indicated that apps primarily serve a supportive rather than a replacement role (Elmali, 2022; Wörner et a., 2022, Park et al., 2019).

Furthermore, we found that the exclusive use of the original animal specimen was high. One possible reason for this is that dissection is an important inquiry and hands-on experience that students want to develop and train during the university course. Dissection provides a real-life experience that cannot be replicated by digital applications and should instead be used to enhance learning. However, it is interesting to note that students preferred original specimen over 3D model despite being given the choice. The timing of the survey may have played a role, as Elmali (2022) conducted their survey before the pandemic and during a period of distance learning, while our survey was conducted after the pandemic-related restrictions and may have emphasized the importance of direct contact with the specimen. The findings will be further be used to develop scaffolds that help students to elaborate their dissection activity using digital tools.

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Domain-specific and Generic Beliefs about Technology Usage in Biology Teaching: Combining a Qualitative and Quantitative Approach

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Theoretical background or rationale

Professional usage of digital tools is predicated upon teachers' professional digital competence, which encompasses, among other components, teachers' professional knowledge and beliefs (Blömeke et al., 2015). In the context of technology integration, the TPaCK model (Koehler & Mishra, 2009) typically specifies teachers' professional knowledge and researchers apply domain- and subject-specific questionnaires for its assessment (Schmid, 2020; Von Kotzebue, 2022). In contrast, teachers' beliefs are often overlooked although it is well known that beliefs about technology integration impacts teachers' technology usage (Fives & Buehl, 2012). For example, they influence if teachers are generally willing to use technology and overcome barriers such as missing infrastructure (Ertmer, 1999). Although there is evidence that teachers' beliefs are grounded in both domain-specific and pedagogical contexts, domain-specific assessment instruments for teachers' beliefs are still lacking (Van Driel et al., 2007; Runge et al., 2023). Regarding the significance of beliefs in teacher education and technology integration, beliefs are rarely studied as domain-specific, interconnected parts of a complex belief system (Fives & Buehl, 2012).

Key objectives

We advocate for the importance of a domain-specific assessment instrument to evaluate teachers' beliefs, as it enables researchers to distinguish between subject-specific and more general pedagogical beliefs held by teachers (Van Driel et al., 2007). This approach would allow for a more precise analysis of the beliefs held by biology teachers and provide valuable insights into how these beliefs develop and how they are influenced in teacher education (Fives & Buehl, 2012). In this study, we concentrate on human biology, which is a traditional yet intricate field of biology teaching that presents ample prospects for utilizing digital tools to improve students' understanding (Fokides & Mastrokoukou, 2018). The research questions are as follows:

RQ1: Which domain-specific beliefs do teachers' hold in the field of human biology and how are teachers' beliefs connected within a belief system?

RQ2: To what extent can a quantitative questionnaire capture the identified beliefs in a reliable and valid way?

Research design and methodology:

In a first study, pre-service teachers' beliefs about the use of digital tools in human biology classes were identified using a three-stage qualitative research design. Data from a survey with open-ended questions (n=105), group discussions (n=24) and guideline-based interviews (n=13) have been analysed with an inductive and deductive qualitative content analysis by two independent coders (κ=61). We used network analysis procedures to examine the interconnections between the beliefs (Koponen et al., 2019) and describe the level of belief- connectedness through statistic parameters (density, transitivity and modularity). Based on these findings a quantitative questionnaire with 60 closed-ended Likert items has been piloted with a sample of n=154 pre-service teachers. We investigated the psychometric properties of the items and scales and checked for factorial, convergent and discriminant validity.

Findings:

For RQ1, teachers' responses (n=691) have been aligned with 18 belief-categories, for example, "beliefs about data collection" or "beliefs about lesson planning". The 18 categories can be aggregated into four main-categories based on their respective content: "subject-specific beliefs", "teaching-learning theoretical beliefs", "negative beliefs", and "infrastructure beliefs". In contrast, findings from network analysis showed that the 18 categories are strongly connected in a belief system, and it is recommended not to further aggregate them based on the statistical parameters (density:0,90, modularity:0,01, transitivity:0,91).

For RQ2, the 60 items were aggregated into 15 scales, which mostly showed acceptable internal consistency (McDonald Ω=.54-.86 for 12 of the 15 scales). Item-discriminatory power was well above r_{it}=.40 for 37 of the 60 items. However, factor analysis shows that the items do not load exclusively on one factor, once again confirming the close linkage of the beliefs.

Conclusions:

There is evidence in the literature that teachers hold both subject-specific and generic beliefs towards technology integration (Runge et al., 2023; Van Driel et al., 2007). The present study confirms this finding for the domain of biology education. Furthermore, we identified through a mixed-method design using network analysis and psychometrical analyses that subject- specific and generic beliefs are closely linked, and it is not recommended to distinguish them based on empirical data. More elaborated analysis methods such as explorative structural equation model (ESEM; Runge et al., 2023) will now be applied to get a better insight into the structure and relationship of the beliefs.

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ChatGPT in biology education: How do AI tools influence conceptual learning?

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Theoretical background:

Evolution education is crucial for understanding biology. Extensive research in evolution education has explored various instructional approaches to enhance students' conceptual knowledge of evolution and has shown that students' intuitive conceptions often persist despite instruction (e.g., Authors; Kampourakis & Zogza, 2009). One viable approach to facilitating students' conceptual knowledge is supplementing traditional teaching with digital media tools. For over five decades, they have been effectively leveraged for education on manifold content, improved digital literacy, and fostered positive attitudes toward digital media (e.g., Dimitriadis, 2020; Serpagli & Mensah, 2021). With the advent of digital media tools based on artificial intelligence (AI), this approach is increasingly central in today's educational landscape. AI tools, such as ChatGPT, can dynamically tailor responses to individual needs, unique questions, difficulty levels, and interests. Therefore, it is torridly debated whether ChatGPT potentially enhances the effectiveness of education or whether the disadvantages predominate (e.g., because of bias or misinformation; Kamalov & Gurrib, 2023; Kasneci et al., 2023).

Key objectives:

Given the relevance of AI in the debate on the future of (biology) education and the lack of studies on the impact of AI on conceptual learning, this study's key objective is to experimentally investigate the influence of ChatGPT on students' conceptual learning. Taking evolution by natural selection as an exemplary biological topic, we explored the research question: *Do students differ in their changes in conceptual knowledge about evolution, self- assessed digital competencies regarding learning with AI, and attitudes toward learning with AI when learning either with AI tools such as ChatGPT or traditional Internet search engines and websites?*

Methods:

We conducted an experimental intervention study using a pre-test, an intervention, and a post- test (for the variables measured, see Table 1) with N = 38 secondary school students (a larger sample will be presented at the conference). For the intervention, the students were first randomly separated into a control (CG; n = 19) and an experimental group (EG; n = 19). The CG received a story about Darwin's journey that was not directly related to conceptual knowledge about evolution, and the EG received information on constructing meaningful prompts for ChatGPT (e.g., by providing contextual details, setting parameters, asking for examples, and refining prompts). Second, we provided both groups with an informational text on scientific key concepts of evolution (e.g., variation) and intuitive conceptions based on cognitive biases (e.g., teleology, i.e., goal-directed explanations of evolutionary changes). Third, both groups were asked to deepen their conceptual knowledge about evolution based on information in the informational text. The CG was instructed to search traditional Internet engines and websites without using AI tools such as ChatGPT, and the EG was asked to prompt ChatGPT.

Table 1

Overview of the measures used in this study

Measure	Description	Items	Pre-/Post-test Cronbach's α
ACORNS (Nehm et al., 2012)	Assessment of conceptual knowledge about evolution by natural selection	2 open-response items; coded: 7 key concepts, 3 cognitive biases	
DiCo (self-developed on basis of the Medienkompetenz-rahmen, 2023)	Self-assessed digital competence regarding learning with AI	5 items, 5-point Likert-type scale[1]	.645/.793
AttAI (adopted of Francis et al., 2004)	Attitudes toward the use of AI for learning and teaching	10 items, 5-point Likert-type scale[1]	.823/.882

Note. [1]For the items rated on a Likert-type scale a high score indicates a strongly positive expression of the characteristic in question.

Findings:

First, we calculated the baseline equivalence for the pre-test results, which revealed no significant differences between the two groups (all *p*s > .10; for descriptive results, see Table 2).

Table 2

Descriptive statistics on the studied variables separated by the groups and time of testings

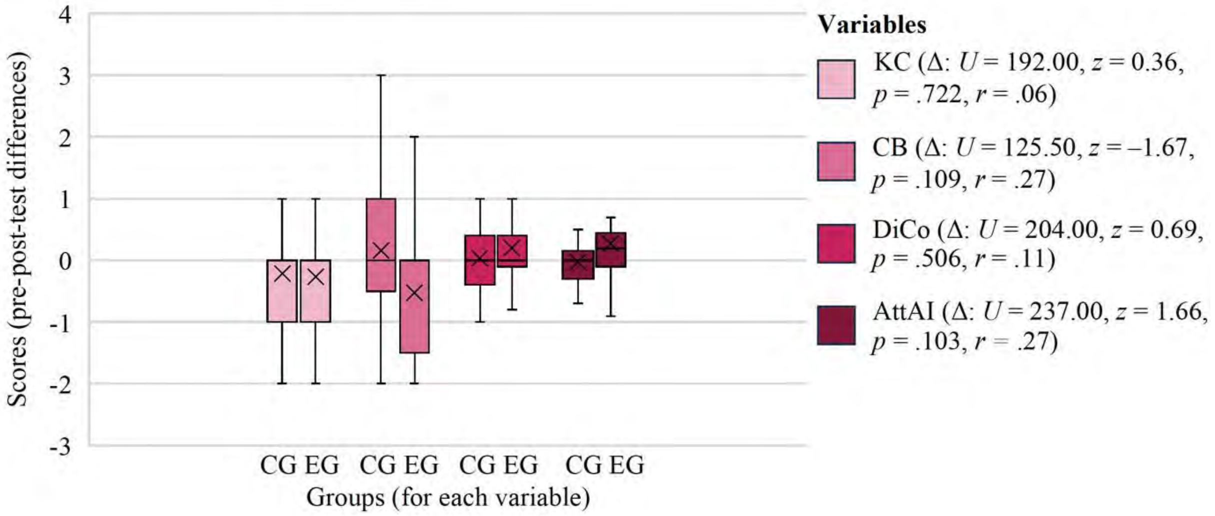
		Pre-test			Post-test		
Groups	Variables	*M*	*SD*	*Mdn*	*M*	*SD*	*Mdn*
CG	KC	1	1	1	0.79	1.32	0
	CB	1.16	0.96	2	1.32	1.2	1
	DiCo	3.58	0.71	3.8	3.61	0.65	3.4
	AttAI	3.77	0.7	3.8	3.74	0.72	3.8
EG	KC	1.16	1.53	1	0.89	1.45	0
	CB	1.42	1.07	2	0.89	0.94	1
	DiCo	3.29	0.67	3.4	3.49	0.78	3.6
	AttAI	3.65	0.6	3.8	3.93	0.67	3.9

Note. KC = Number of used key concepts in the ACORNS items; CB = Number of used cognitive biases in the ACORNS items; DiCo = Self-assessed digital competence regarding learning with AI; AttAI = Attitudes toward the use of AI for learning and teaching.

Furthermore, we analyzed the proposed research question using Mann-Whitney-U tests. The results indicate no statistically significant differences between the two groups regarding the pre-post-test differences (e.g., increase/decrease in the scores) of the variables displayed in Figure 1.

Figure 1

Boxplots representing group differences in the selected variables



Note. CG = Control group; EG = Experimental group; Δ = Differences between the groups; KC = Number of used key concepts in the ACORNS items; CB = Number of used cognitive biases in the ACORNS items; DiCo = Self-assessed digital competence regarding learning with AI; AttAI = Attitudes toward the use of AI for learning and teaching.

Conclusions:

Although there were no statistically significant differences between the groups, we argue that the results indicate a practical relevance. Similar to findings showing that chatbots can foster knowledge (e.g., Dimitriadis, 2020; Kamalov & Gurrib, 2023), our descriptive data suggests that the instructions of the EG reduced intuitive conceptions based on cognitive biases. Furthermore, it indicates an increased self-assessed digital competence regarding learning with AI and more positive attitudes towards using AI from pre- to post-test. Since we identified moderate effects of the interventions (see Figure 1), it can be assumed that these will be statistically significant when analyzed in the targeted sample size with sufficient test power. Overall, the results imply potential benefits associated with the integration of ChatGPT as an instructional tool in biology education. Incorporating it into educational settings may alleviate educators' workload by allowing assistance in effectively personalizing educational input (e.g., Dimitriadis, 2020). Despite these advantages, common risks of ChatGPT that are, for instance, related to the credibility of information, should be controlled by educators and policymakers to avoid misinformation. Additionally, students might benefit from critically reflecting and validating the AI-constructed chat responses (e.g., Kamalov & Gurrib, 2023; Kasneci et al., 2023). To draw further implications for integrating AI tools in biology education, we will present qualitative analyses at the conference regarding how students interacted with ChatGPT (e.g., quality of students' prompts; included key concepts and cognitive biases in ChatGPT's output) and to what extent they critically evaluated ChatGPT's output.

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Pre-service teachers' beliefs on the subject-specific use of digital media in biology classrooms

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Roundtable

Health Education

Positioning Teachers Engagement on Health and Vaccine Issues

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The term "health" is a broad and deep concept that involves science, economics, politics and social aspects. This aspect of health is one of the demands stated in the charter for human rights education (Robinson; Phillips & Quennerstedt, 2020). With the phenomenon of the COVID- 19 pandemic, science topics, especially those involving vaccination and health, have been the target of the proliferation of fake news in societies, causing great turmoil and posing a challenge to science education processes for the 21st century (Reiss, 2021). In this way, the training of science teachers in health and vaccine issues is one of the important axes for teaching-learning processes. Training could be focused on disinformation and scientific literacy not only linked to the transmission of scientific knowledge, its technological applications and everyday life, but to the processes of emancipation, political participation and social transformation of students (Valladares, 2021; Morin & Dutreuil, 2022).

Within this perspective, one of the major problems reported by teachers in articulating these perspectives in the classroom is linked to the opportunities for training processes in skills and competences for developing these themes in lessons (Ladage, 2016; Bernard et al., 2021). One of the challenges for biology teaching is to develop teacher training that articulates socio-political- scientific perspectives on health issues in a critical way and that is linked to scientific practices, such as argumentation, in the classroom. How can we build teacher training that fosters the development of these skills and competencies? There are still few tools for assessing teachers' positioning and engagement with socio-political-scientific knowledge in health, which can influence the construction of their lessons. The research hypothesis was to develop and use a theoretical, and methodological tool for analyzing the arguments of workshop participants. This tool could help us diagnose the needs and gaps in socio-political-scientific approaches, and so that it can help make decisions in the training processes of biology teachers with health themes for science classes.

The aim was therefore to evaluate, as a proposed study model, the position of a group of master's degree students (n=3) participating in a training workshop on the approach to vaccination issues when developing dissertations on the subject of infectious diseases and health for science classes. This evaluation was carried out during the students' participation in meetings/workshops held by the "HeTeaching" project (Heath Teaching) [MSCA-UE/CREAD/INSPE/UBO, France], in the year 2022-2023 [2 hours duration each], in the axis of teacher training, production and analysis of teaching sequences. In order to carry out this evaluation, a questionnaire was constructed to capture three dimensions of the engagement of argumentative competences and skills, based on the proposal of the European program for research and innovation Horizon 2020 (Ivani & Dutilh, 2022) and regarding the evaluation of the use in practices in science classes: 1) valid or uncertain arguments; 2) contradictory arguments; 3) controversial arguments (vaccine hesitation). The positioning of the participants was analyzed using an adaptation of the 4 categories proposed and constructed by Morin & Dutreuil (2022) in the engagement of subjects with socio- scientific themes: i) "Knowledgeable", that individual who mobilizes scientific knowledge; ii) "The expert", that individual who mobilizes scientific knowledge to solve concrete problems in society; iii) "The enlightened citizen", that individual who mobilizes scientific knowledge and recognizes its application and importance in society; and iv) "The engaged citizen", that individual who mobilizes political knowledge in conjunction with social and scientific knowledge.

Analysis of the results showed that: 1) the participants are in agreement (n=2) and absolutely in agreement (n=1) that addressing the topic of vaccines and vaccination can lead students to distinguish between valid and uncertain knowledge on the topic; 2) the participants are in agreement (n=2) and absolutely in agreement (n=1) that addressing the topic of vaccination implies addressing contradictory arguments on the topic; and 3) they are in absolute agreement (n=2) and agreement (n=1) that addressing the topic of vaccine hesitancy in science classes is pertinent to students' learning. This set of analyses suggests that the participants have adherence and engagement with social-scientific approaches to vaccine issues. The analysis of the written arguments developed by the participants showed that the levels of positioning are classified in the categories of "Knowledgeable", i.e. their perspective of their science teaching is based on scientific knowledge and the logic of science; and "Enlightened citizen", i.e. their perspective of science teaching is to provide a practical application of science in everyday life and society. This set of analyses suggests that the participants value scientific knowledge and its applications in society, but that they do not yet articulate it with political knowledge within the framework of democratic participation as a citizen engaged in vaccination issues.

In conclusion, our study suggests that the analysis framework proposed by Morin & Dutreuil (2022) could be a model for a significant evaluation tool in characterizing the position of participants in teacher training processes on socio-political-scientific issues in science and health. In perspective, this type of analysis can provide important data to guide teacher trainers engaged in scientific processes, transformation and social justice involving socio-scientific issues in biology classes.

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South african pre-service life science teachers' covid- 19 vaccination status, knowledge and behavioural intentions

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Theoretical background or rationale
The HIV/AIDS epidemic and COVID-19 pandemic have significantly impacted global health, with acute effects in developing countries like South Africa (Sun et al., 2022). Key challenges include misconceptions, stigma, vaccine hesitancy, and socio-cultural factors. A multidisciplinary approach involving health, education, and socio-economic sectors is vital for effective public health interventions. Life Science teachers could play a critical role in public health, particularly in disseminating health-related information and modeling safe behavioral intentions (El Islami et al., 2023). Therefore, collaboration between teachers and healthcare professionals can potentiate the efficacy of health education. However, this collaboration is undermined when teachers exhibit vaccine hesitancy, often due to misconceptions about vaccine safety (Cima et al., 2022). Addressing these misconceptions and vaccine hesitancy among teachers is imperative, as their attitudes and behaviors could directly influence community perceptions and could jeopardize public health initiatives.

The current study addresses a gap in Life Science education and public health research by examining the factors affecting COVID-19 vaccine uptake among pre-service Life Science teachers in South Africa. Traditional focus on the general population or healthcare providers has overlooked this group's role in shaping public health outcomes. By investigating knowledge and attitudes as determinants, the study aims to inform targeted interventions to boost health literacy vaccine uptake and tailor science curricula for enhanced health literacy. Teachers' beliefs and behaviors have a long-term societal impact, making this research critical beyond the scope of the COVID-19 pandemic. Ultimately, the study seeks to contribute to a sustainable, multidisciplinary approach in public health policy and science education, fostering scientifically literate communities better prepared for future health crises.

Key objectives:
The current research aimed to investigate the relationship between knowledge, behavioral intentions towards vaccination, and vaccination statuses among pre-service Life Science teachers in South Africa. The research question is: "*What is the relationship between COVID- 19 vaccination status, knowledge, and behavioral intentions towards COVID-19 vaccination among pre-service Life Science teachers in South Africa?"*

Research design and methodology:
This research followed a quantitative approach utilizing a non-experimental survey for data collection through an online closed-ended questionnaire. Participants were 183 purposively selected final-year Bachelor of Education (Life Sciences) pre-service teachers from a South African university. Participation was voluntary, and the research received approval from the ethics committees of the host university. The instrument was designed to gauge three specific domains: vaccination status, knowledge of COVID-19, and behavioral intentions toward COVID-19 vaccines among the participants. Data analyses involved descriptive and inferential statistics through SPSS.

Findings:
Results showed that 66% of participants reported being fully vaccinated, and 33.3% were not vaccinated. Regarding vaccine knowledge, 36.1% of the participants scored over 70%, and 29.5% scored above 80% on Covid-19 knowledge. Significant misconceptions were noted where 79% of the participants believed the Covid-19 vaccine increases the risk of infection, 15% believed the Covid-19 vaccine changes human DNA, 27% believed the Covid-19 vaccine changes human RNA, and 28% believed Covid-19 vaccines carry a tracking microchip. Data also showed that understanding COVID-19 symptoms positively relates to vaccination status. Misconceptions were negatively related to vaccination status.

Positive behavioral intentions were reported, with over 88% of respondents displaying a positive attitude towards the vaccine. Negative behavioral intentions were identified concerning normative beliefs and perceived behavioral control. The regression model showed that behavioral intentions towards COVID-19 vaccines significantly predict vaccination status. COVID-19 Knowledge also significantly influences vaccination status, though to a lesser extent. However, Vaccine Knowledge was not statistically significant in predicting vaccination status.

Conclusions:

The current research aimed to explore the intricate relationship between vaccination status, knowledge, and attitudes towards COVID-19 among pre-service science teachers in South Africa. The current research found that many participating pre-service science teachers in South Africa reported receiving the COVID-19 vaccine. This finding echoes the larger patterns of vaccine uptake reported in the literature (e.g., Malesza & Sobolewska, 2021). It was also found that while general knowledge about the virus and its symptoms was high, gaps existed in comprehending the link between COVID-19 and SARS-CoV-2. This is aligned with prior work (e.g., Chen et al., 2021; Kabeta et al., 2022), which reported high levels of COVID-19 understanding among teachers in Zambia and Malaysia, respectively. The findings corroborated research reporting significant COVID-19 misconceptions among teachers (e.g., Debela et al., 2023). The current study validates that teachers are generally seen as informed individuals (El Islami et al., 2023), but they are not immune to harboring misconceptions about COVID-19. Given their role in community education, this is concerning and points to the risk of perpetuating misinformation.

In conclusion, while knowledge and positive attitudes towards COVID-19 vaccines were generally high among pre-service science teachers, gaps and misconceptions need to be addressed through targeted educational programs. This research contributes to a better understanding of factors affecting vaccine uptake. It provides an empirical foundation for educational interventions designed to improve vaccination rates among future science educators in South Africa.

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Raising students' ability to assess the reliability of information in the context of viruses and vaccination

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Theoretical background

Exposure to disinformation, including conspiracy theories and pseudoscientific information, has become a part of our daily lives. Despite the raised level of education and standard of living, the number of people adopting beliefs patently at odds with observable reality and scientific evidence is a growing concern. It also makes it harder to fight global problems, such as pandemics and make well-considered health-related personal decisions. Research has also shown that traditional methods for teaching science are weak means to challenge alternative conceptions (Osborne et al., 2022). Therefore, science education should focus more than before on developing students' ability to assess the reliability of information presented by various media (Barzilai & Chinn, 2020; Alchin, 2020; Osborne et al., 2022). The development of these skills cannot be blamed solely on social studies, as a large part of mis- and disinformation claims are related to science (Osborne et al., 2022; Authors, 20XXa).

Key objectives

This study proposes a teaching strategy which is represented by a learning module "Viruses" to:

- Foster students' (age group 16-17) ability to assess the reliability of information.
- Impact their acceptance of public myths about viruses and vaccination towards being more aligned with the current scientific evidence.

Research design and methodology

The module (see Figure 1) starts with a staged video to introduce public opinions (myths) about viruses and vaccination, followed by a group discussion and opting out of a myth to be further busted (Authors, 20XXb).
Through inquiry learning (myth-busting), students are expected to gather evidence about the chosen myth by juxtaposing media/data sources and their content, critically analyzing their reliability using an *information reliability tool*, and, depending on the myth chosen, conducting an experiment. This is followed by making a justified conclusion. To learn how to communicate their evidence, students are guided to produce a video of their experiment or use other digital visualization (e.g., visual facilitation) techniques. The presentation of their findings, together with peer-assessment, follows this.

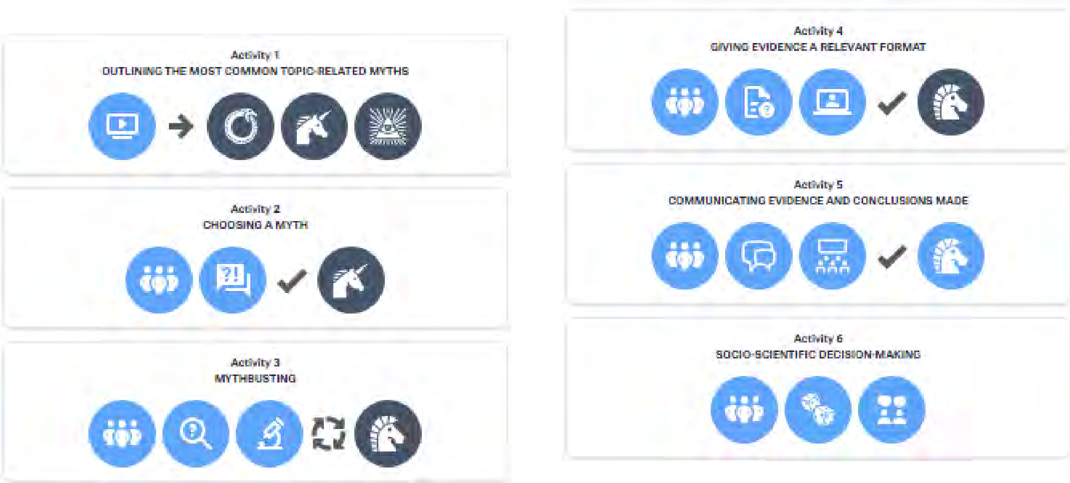

Figure 1. Learning sequence of the Viruses module

In the final step, the storyline of the module returns to the initial video and presented myths. Based on the lessons learned from the earlier steps, students prepare to make decisions on an individual and group level in the format of a board game, where they have an opportunity to juxtapose, reflect on, and consolidate their new knowledge with their personal beliefs.
The module "Viruses" is tested in two steps. In the pilot step, the module was taught in two Estonian schools to a sample of students (N=51, age group 16-17, 10th grade) by their ordinary biology teachers

within an integrated science course. Both teachers were participants in the current project. The main study will be conducted in January … May 2024 in four Estonian schools (Nstudents>100, age group 16-18). Data were/will be gathered by a combined questionnaire from the students before and after teaching the module. In the second step, the module is taught by teachers who have participated previously in a teacher-in-service course promoting the current teaching approach.
A paired-sample t-test was/will be conducted on the gathered data to evaluate the impact of the module on the students' self-reported ability to assess the reliability of information (scale was adapted from Eristi & Erdem, 2017) with five items and the acceptance of public myths related to viruses and vaccination covered by the module, with ten items.

Findings

The results of the pilot study can be seen in Table 1 and 2.

Table 1. The pilot students' (N=49) self-reported media literacy skills measured before and after teaching the module on a five-point Likert scale

Statement	xpre	xpost	t*	p
1. I can make a difference between reliable and unreliable information	3.53	3.94	+4.06	**<0.001**
2. I can recognize the tactics via false information is shared on the internet	3.67	3.82	+1.31	0.197
3. If I find controversial information on the internet, I usually check the other sources to decide whether it can be trusted or not	4.01	4.12	+0.33	0.743
4. It is easy for me to distinguish evidence-based information from non-evidence based	3.23	3.31	+0.28	0.780
5. I can identify biased, vicious and/or harmful media content	3.78	3.88	+0.48	0.632

*Xpost - Xpre

Table 2. The pilot students' (N=51) acceptance of viruses and vaccination-related public myths measured before and after teaching the module on a 5-point Likert scale

Statement	Xpre	Xpost	t*	p
1. Immunity acquired through disease is a better choice than immunity acquired through vaccination.	2.86	2.52	-2.45	**0.018**
2. Vaccines can infect children with the disease it is trying to prevent.	2.17	1.88	-2.05	**0.046**
3. Vaccines contain life-threatening substances.	2.54	2.48	-0.36	0.718
4. Vaccines cause serious side effects.	2.56	2.31	-1.90	0.063
5. Infant immune systems cannot handle multiple vaccines simultaneously.	3.06	2.46	-4.16	**<0.001**
6. We do not need to vaccinate because infection rates are anyway low in many countries.	1.52	1.54	+0.23	0.821
7. Better hygiene and sanitation are responsible for decreased infections, not vaccines.	2.96	2.77	-1.46	0.151
8. Soap is as good as alcohol for killing certain viruses (e.g., COVID-19).	2.56	2.98	+1.92	0.060
9. Masks are pointless in preventing upper respiratory diseases (e.g., COVID-19).	2.15	1.81	-2.76	**0.008**
10. Prolonged use of the mask produces hypoxia (lack of oxygen).	2.83	1.82	-5.58	**<0.001**

*Xpost - Xpre

Conclusions

Pilot study results showed a slight positive impact of learning the Viruses module on the students' self-reported ability to assess the reliability of information presented in the context of viruses and vaccination. However, the changes were not always statistically significant. A diminishing effect on the students' acceptance of the virus and vaccination-related public myths was detected except for statement 6, which was explicitly addressed in the main study, and statement 8, which was almost correct). The main study findings will be presented and discussed in the conference.

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Learning about nutrition through play

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Theoretical background – key objectives

It is well known that a healthy diet is extremely important for human health and development. A previous study revealed that Greek adolescent students' knowledge about nutrition is limited and fragmented concerning all nutritional groups, while they seek information mainly on the internet and their parents and much less in school, which rarely offers appropriate educational programs but not solid knowledge since the curricula include few relevant concepts. (author, 2023). Furthermore, they have a reduced consumption of fruit and vegetables preferring unhealthy foods, while Greece has very high rates of childhood obesity (Bebetsos et al., 2015).

For all the above reasons, we decided to design educational material that can be easily used in the classroom. We ended up designing an educational game as their integration helps to enhance learning motivation, active participation while enhancing social and problem-solving skills of students (Misra et al., 2022). We focused on card games because they are entertaining, maintain direct interpersonal interaction between teachers-learners and among learners (Liu & Chen, 2013) and are fairly easy and inexpensive to create.

Methodology

Constructing the educational game "Food for good" (FG^2) we would like to ensure that students will come in touch with all nutritional groups and their nutritional value. We, also, considered that this game should be easy to play in the classroom so that it could function as a supplementary educational material since the school curriculum is very poor in nutritional concepts.

Finally, we decided to give a character of familiarity and everyday life by choosing to include foods that belong to the daily and usual diet of Greek adolescents to attract their interest not only through the alternative educational approach offered by a game, but also through its content. Thus, 40 cards were designed. On the front side of the card, information about the qualitative composition of a food and some information about the correlation between this food and human health is shown, as well as similar suggestions. On the reverse side there are 4 pictures, one of which is indeed the one to which the description on the front side belongs. Thus, the cards per quartet had the same back side and different front sides (figure 1).

The rationale for designing the quads was to group "similar" foods. This resulted in the following groups: fruit, dairy, protein foods, drinkable foods, snacks, vegetables, processed foods. We felt it was very important to include processed foods, as if students are only exposed to each category of unprocessed foods, they are likely to gain relevant information and knowledge, but we do not ensure that they will be able to make the necessary combinations in the case of processed foods, which is quite essential.

To ensure maximum participation and engagement of students, specific rules were established (figure 2).

Figure 1. Card of the educational nutrition "Food for good" game (FG^2)

The game was piloted with 49 K-10 students. After playing for 3 instructional hours, they were asked, in groups of 5, to draw a poster of a day's diet by choosing between different foods given to them (after 2 weeks). All food groups were included in their choices and care was taken to include foods from their daily lives, but not necessarily the same as those of FG^2. The same was asked before the game was implemented so that a comparison could follow to see whether their choices were approaching or deviating from a healthy-balanced diet after the game. At this stage, we were interested in a first insight into the educational value of FG[2] and its effectiveness in terms of managing the adolescents' daily food choices, in order to take the necessary corrective actions. This approach allowed us to explore both students' knowledge and intentions on a topic that involves health implications.

Rules

This game can be played either with 2 players or with 2 teams of 2 players each. One player also needs to take the role of referee. All players will need to go through the referee position, so the game should be played for as many rounds as the number of total players.

Part 1	Part B
Players have 10 random cards in their hands. After rolling a die to determine who will play first, they begin to take turns and their goal is to take their opponent's card. To do this, one player describes the food on the card and based on the information provided, the opponent must choose which food the card refers to. They need to listen carefully to the information given and concentrate on the information that will lead them to the correct choice. If a player is wrong in their final choice after the description, then the opponent keeps the card they described. The game ends when all 20 cards have been described.	The winning student/team is asked to select and place on the Food Pyramid the foods they consider to provide a complete and healthy daily diet. They have the right to take 2 cards from their opponent if they deem it necessary. On completion of this phase, the referee checks that the choices are correct with the help of a pyramid at their exclusive disposal. If the referee judges that the choices are in accordance with the rules of healthy and balanced diet, then the winner is the player/team who made the correct placement. If not, the other player/team is given the right to make some changes and if they manage to correct the mistakes then they win.

Figure 2. The rules of the game

Findings - conclusions

The results of the posters' design are shown through the illustrative figures 3, 4. For all groups it was evident that there was an improvement in terms of either the quality of the food chosen overall, or the number of meals included or even the reference to drinking sufficient water.

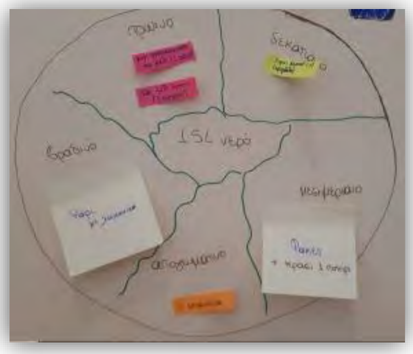

Figure 3. Daily diet (before playing the game) Figure 4. Daily diet (after playing the game)

Many more appropriate food combinations were also observed. However, it cannot be said that complete success was achieved. Four groups still made unhealthy but popular, among adolescents, choices (i.e., junk food). In these cases, however, we observed a common pattern: breakfast and one unhealthy main meal were included, whereas before the game only two unhealthy main meals were included. Possibly, they felt that in this way they were balancing their menu (concerning the caloric load). Of course, this misconception is important to be removed, but we dare to say that an encouraging signal about the identification of unhealthy foods is derived. Our results are consistent with other research showing that game- based teaching interventions focused on nutritional topics were significantly effective in enhancing students' learning and attitudes (e.g., Yien et al., 2011).

However, toreach the final version of FG[2], in terms of achieving its educational objectives, we believe that (a) enrichment with additional cards, (b) more time for its implementation and perhaps (c) redefinition of the rules at some points are needed. Therefore, this is our next step, so that FG^2 becomes a potential educational tool that, with the appropriate adaptations, could contribute to education (within and outside the Greek borders).

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Posters session 3

Teaching learning sequence for heredity: the learning outcomes

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Cats on the run – meaning making of evolution in primary school

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Theoretical background:
Evolution can be difficult to understand for both students (Legare et al., 2013), university students (see, e.g., Fiedler et al., 2017; Meir et al., 2007) and adults (see, e.g., Spiegel et al., 2006). At the same time, several studies (e.g. Emmons et. al, 2017; Frejd et. al, 2022; Jégou et al., 2022) show that there are good conditions for children to understand the basics of evolutionary processes if they are allowed to encounter the subject in age-appropriate activities. Something that has proven to be important is that children in education get access to materials, such as pictures, which they can use as multimodal resources in the creation of meaning and in conversations with each other and with teachers (Frejd, 2018; 2019; see also Jégou et al. , 2022). Comics are a multimodal medium that combines several forms of expression that can be used as fruitful teaching tools (Spiegel et al, 2013; Wallner, 2017).

Key objectives:
Teaching about evolution and biological diversity have been pronounced for years 4–6 in a recent Swedish curriculum revision (LGR22). To meet teacher needs for new teaching tools we have produced a comic book together with a professional illustrator that illustrates evolutionary patterns and processes. The comic book *Cats on the run* presents a narrative where two kittens travel through space and time and meet extinct and now living cat species. The story of the two kittens' adventures offers a material that stimulates meaning making about central concepts of evolutionary processes (variation, natural selection, heredity) and evolutionary patterns (adaptations).
The purpose of the study was to investigate students' experiences of interaction with the new teaching material. In particular, we are interested in which evolutionary processes are expressed and which aspects of the content of the material that seem to promote meaning-making about evolution.

Research design and methodology:
We recruited 10 teachers from different schools in Sweden who used the comic book together with a teaching guide in year 4-6 classes during the spring 2023. After they finished the teaching module about evolution, the pupils shared their experiences in a digital survey with both closed and open items. The open answers (N=169) were analyzed with content analysis (David & Sutton, 2016).
To explore and exemplify student interaction with the comic material we visited three teachers in three different schools where we followed a total of five lectures. Observation protocols, teacher notes and video recordings from these visits are used as supportive data in the present study. A more fine grained analysis will be presented later.

Findings:
The students are generally positive about the comic and seem to appreciate fictional frame in science education. The qualitative analysis of student descriptions of what they have learnt while working with the comic in science class show that they spontaneous mention several central concept such as variation, heredity, and adaptation. In addition, some students comment on the connection between evolution and the current problem of loss of species.

Conclusions:
The project shows that the produced comic book can be a fruitful way to teach evolution in primary school.

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Digital media in primary school science lessons - an interview study with (future) science teachers

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Theoretical background:
Digitalisation has long played an important role in everyday life. The conference of ministers of education in Germany therefore published the action plan "Education in the digital world" in 2017, with the aim of being able to offer every student a digital learning environment at all times by 2021. Germany is currently still far from reaching this goal (Kerres, 2020). Access to information, communication possibilities and participation in society are strongly influenced by digital possibilities (Glüer, 2021). It is therefore essential to teach students media skills that will enable them to use media safely, creatively and responsibly (Medienberatung NRW, 2020). Schultz-Pernice et al. (2017) see the media competences that students should achieve as the minimum that teachers should also have. The Monitor Digitale Bildung (2017) shows that there is a low use of digital learning media in teacher education. Furthermore, they are only poorly motivated by using them (Schmid et al., 2017). Vogelsang et al. (2019) were able to show that future teachers with at least one science subject have little background experience with digital tools. For the teaching of media skills primary schools play a special role in this (Herzig, 2020). The science teaching is particularly ideal for learning with and via digital media, due to its world-opening core task and the multi-perspective principle (Kunkel & Peschel, 2020).

Key objectives:
For this reason, (future) science teachers were interviewed.
Research question: The following research questions will be addressed in this interview study:
- How do future science teachers and science teachers define digital media and what experiences can they report from the school context?
- What advantages and disadvantages do the teachers report with regard to the use of digital media?

The results will be used to draw conclusions for the future design of teacher training programs at the university with a focus on digital media and their implementation. Likewise, further training for actual teachers could be created on the basis of the material.

Research design and methodology:
The interviews are carried out using an interview guideline. This guideline contains questions on various aspects of digital media. The guideline interview method was chosen because it gives a general structure to the interview, there is still room for flexibility in the process (Döring & Bortz, 2016).
For the available material, the content-structuring qualitative analysis of data according to Kuckartz and Rädiker (2022) is used. All process steps are run through and complemented by iteration and feedback steps. The formation of categories happens in an inductive way. A detailed code manual is prepared for the fixation.
To check the quality of the analysis, the intercoder reliability is then calculated. The entire analysis was carried out using the MAXQDA 2022 software. The statements are straightened out in language for better readability. To illustrate the results, the anchor examples are translated into English. This procedure does not falsify the material.

Findings:
At the moment, interviews are being taken with the teachers of science for the primary school. By the time of the conference, the study will be completed and approximately 35 future and actual teachers interviews will have been analysed in order to be able to present specific results. In this way, it should be possible to record the status quo of the opinions and attitudes of (future) teachers in science education. The first results show that the future teachers do not have a clear definition of digital media. Almost only examples are used for the definition. Likewise, all of them name possibilities of use that they know for digital media. However, these are not diverse, so that many media competences are not taken into account.

Conclusions:
According to Süss et al. (2018) a competent handling of digital media is a process of development and thus a central task of lifelong learning. Kramer and Gabler (2022) highlight that it is important to develop the use of digital media and the media competence of future teachers.

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Effects of a Training with Incremental Scaffolds on Students' Cogni- tive Load and Knowledge Acquisition during Experimentation

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Theoretical Background

Cognitive overload is likely to occur when students experience little support during experimen- tation (Kirschner et al., 2006). The *extraneous cognitive load* describes the load caused by in- efficient instructional designs, such as unguided problem-solving or the way information is presented (Sweller et al., 2019) and thus can be influenced by appropriate instructions. Free working memory capacities might allow for the construction of schemata and therefore learning (Skulmowski & Xu, 2022). In order to assist students during experimentation, they can be pro- vided with incremental scaffolds, which are sequential written solution instructions (Schmidt- Weigand et al., 2009). Even though studies have shown a positive impact of incremental scaf- folds on knowledge acquisition (Großmann & Wilde, 2019), Kleinert et al. (2021) could show that students had difficulties in using them properly. Other research indicates that positive ef- fects of incremental scaffolds might only occur after a repeated use (Hänze et al., 2010), so a training with incremental scaffolds should be considered (Stiller & Wilde, 2021). Therefore, a training phase concerning the use of incremental scaffolds was implemented in the present study to build and improve students' skills and abilities through repeated practice and reflection of this method (Fries & Souvignier, 2009).

Key Objectives

The key objective of the present study was the investigation of a training phase regarding the use of incremental scaffolds compared to its one-time use (without training) on students' knowledge acquisition during experimentation in biology classes. Extraneous cognitive load was also assessed to test whether the incremental scaffolds could lower extraneous load or were even perceived as additional material and might thus add to cognitive load, which would hinder effective learning. The research question reads as follows:

Does a training phase regarding the use of incremental scaffolds affect students' cognitive load and knowledge acquisition during experimentation in biology classes?

Research Design and Methodology

The quasi-experimental study was conducted with 153 students (M_{age}=13.5 years, SD_{age}=0.55) in the seventh and eighth grade of two grammar schools. Students in both treatments received the same lessons, but the 'Training-Group' (*Tr*; *n* = 77) received support during every of the four model experiments in form of three incremental scaffolds per experiment (1. planning und conducting; 2. observation and evaluation; 3. conclusion), while the 'No-Training-Group' (*NoTr*, *n* = 76) only used incremental scaffolds in the fourth experiment (see Figure 1). The treatment group additionally underwent a reflection phase on the use of incremental scaffolds after the first three experiments. After each experiment, extraneous cognitive load was assessed in both treatments via three items (Klepsch et al., 2017) on a self-report scale and analyzed via a mixed-ANOVA. This statistical method was also used for the analysis of the self-developed knowledge test, consisting of four items measuring procedural and four items measuring con- ceptual knowledge acquisition.

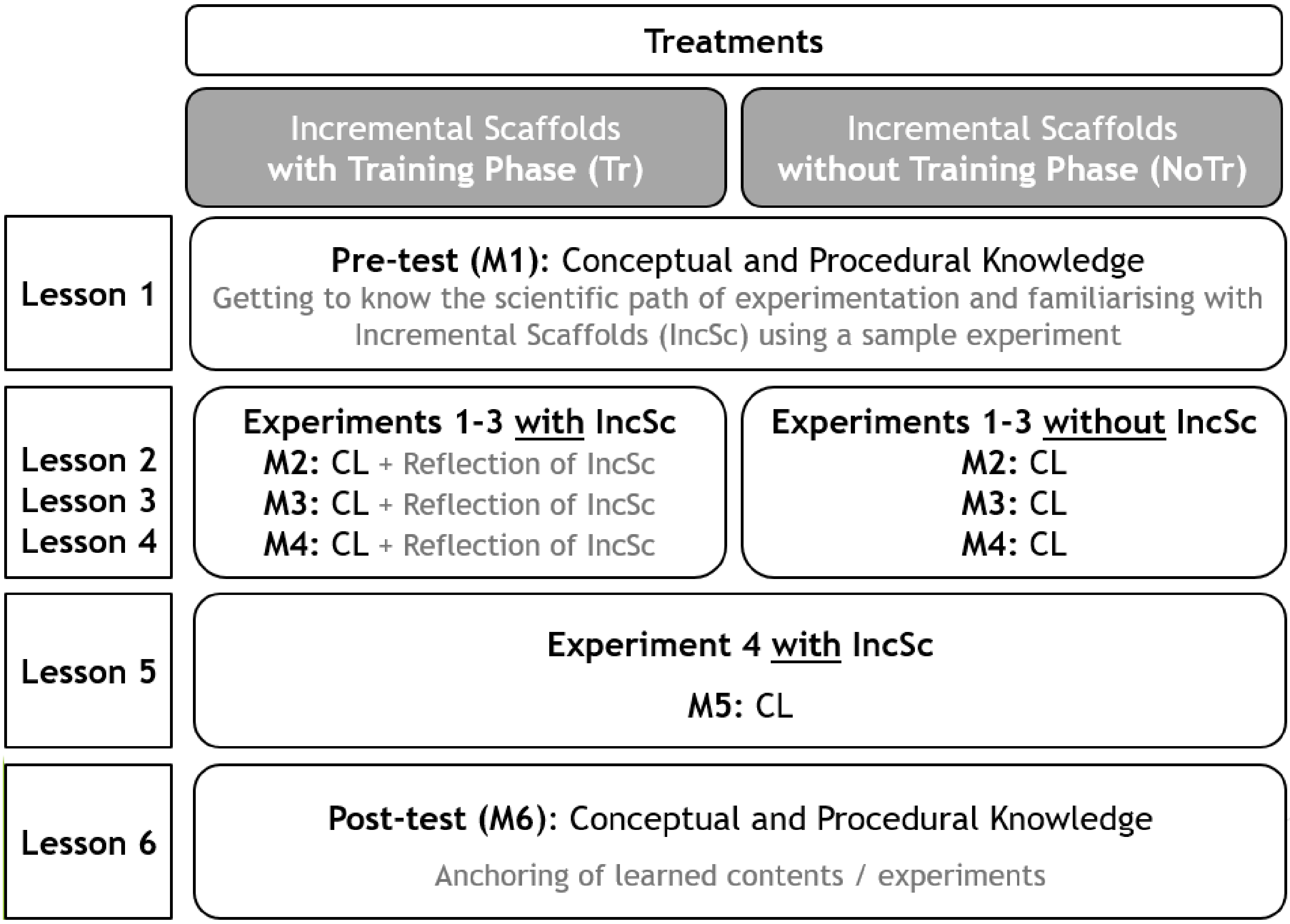

Figure 1: Study Design; M1-M6 = Measurement points; IncSc = Incremental Scaffolds; CL=Cognitive Load

Findings

In every of the four experiments, the mixed-ANOVA revealed no significant differences in extraneous load (interaction effect: $F(1,105)= 0.484$; $p=.694$, $\eta^2=.014$) and procedural knowledge acquisition between experimental and control group (interaction-effect: $F(1,127)= 0.917$; $p=.340$, $\eta^2=.007$). With regard to conceptual knowledge, there was a significant interac- tion effect with the treatment (interaction-effect: $F(1,127)= 9.850$; $p=.002$, $\eta^2=.072$).

Conclusions

The present research could show that a training phase regarding the use of incremental scaffolds appeared advantageous. Overall, extraneous cognitive load, as a precondition for knowledge acquisition, was not increased by incremental scaffolds, so resources for schema construction and thus learning were available to the same degree in experimental and control group. A pos- sible reason for not finding any significant differences in procedural knowledge acquisition could be reducing the number of incremental scaffolds to three by combining certain experi- mental steps. Even though, extraneous cognitive load was not increased this way, the support via incremental scaffolds was potentially less process-oriented. Additionally, also students of the control group might got used to the way experiments are conducted and gained a similar understanding of process-oriented skills within experimentation due to repeated practice. Future research could investigate the design and use of incremental scaffolds that potentially address both, conceptual and procedural knowledge.

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Enhancing biology education: harnessing inaturalist to empower future biology teachers

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Theoretical background or rationale

iNaturalist is a website and mobile application that aims to serve as a social and citizen science (CS) platform for all naturalists (Aristeidou et al., 2021). CS is an expanding field in public education and can connect science and society with authentic scientific questions that can help students to familiarise themselves with research and their personal role in it (Lüsse et al., 2021; Bonney et al. 2014). The effects of using CS in the classroom are found in the literature in the following areas: Interest, self-efficacy, motivation, scientific inquiry skills, behavior and responsibility, and the nature of scientific knowledge (Lüsse et al., 2021). Biological keys are critical in learning the names of species (Beeber et al., 2004). The use of applications such as iNaturalist could help make the learning experience fun by providing a platform where students can create digital herbaria and spark their interest in the biodiversity around them (Aristeidou et al., 2021; Echeverria et al., 2021; Unger et al., 2021). For this reason, learning more about the impact of iNaturalist and similar applications on future biology educators' interest in nature and science is crucial, as it will strengthen them in their own professional teaching practices (Paradise & Bartkovich, 2021; Hitchcock idr., 2021).

Key objectives:

The primary aim of this research was to evaluate utilization of iNaturalist application among students at the tertiary education level, with the overarching goal of enhancing their learning experience, fostering interest in and self-efficacy concerning natural sciences.

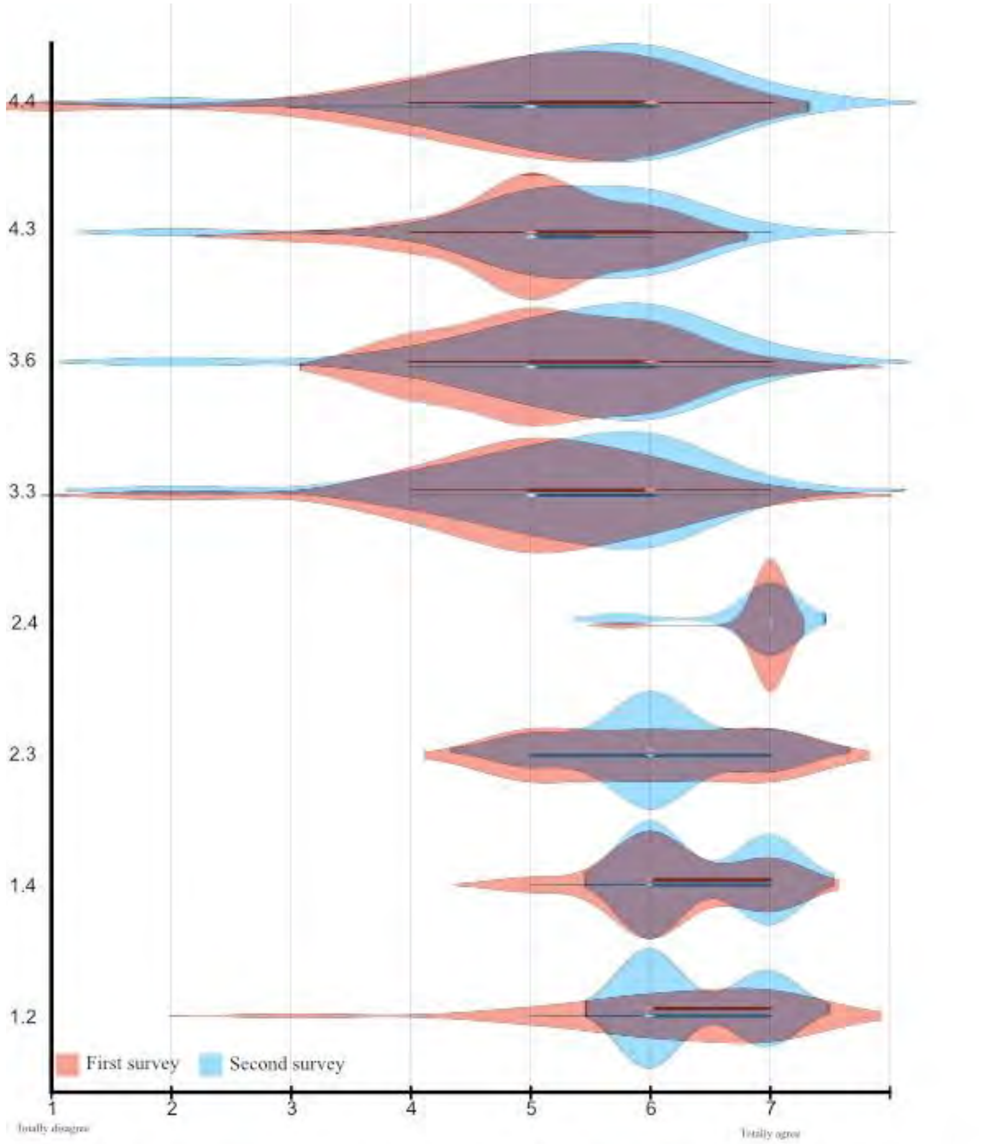
Research design and methodology:

A group of first-year two subject teachers (one subject being biology), at University of Ljubljana, Faculty of Education, Slovenia was selected, employing a purposive sampling technique. Prior to commencing the activity, students were required to complete a survey by Smith et al. (2021) which was translated into Slovenian. Selection of this survey instrument was predicated on its alignment with socio-cognitive constructs that resonated with our study's objectives. Social constructs surveyed were interest in nature and science and self-efficacy for environmental action and for learning and doing science.

Following this, a one-month iNaturalist activity was conducted. Students were tasked with collecting 30 species observations from various organism groups, and 20% points to the final grade incentive was offered upon successful completion. Students then collected and identified organisms. Afterward, a second survey was administered, gathering feedback on likes, dislikes, and suggestions for future activities.

Findings:

Preliminary results are presented. For each of four dimensions from a survey by Smith et al. (2021) two items are presented.



1.2: I like to observe birds, butterflies, bugs, or other things in nature.

1.4: I like learning about the wildlife that lives in my community.

2.3: I believe that I personally, working with others, can help solve environmental issues.

2.4: It is important for humans to protect species from extinction.

3.3: I enjoy reading about science-related topics.

3.4: Other people would describe me as a »science person«.

4.3: I think I'm pretty good at understanding science topics.

4.4: I feel confident in my ability to explain science topics to others.

Figure 1: Students' agreement with selected items. Dots in the plot represent median values and the thick lines represent interquartile ranges.

Notably, students (*N*=22) scored high on items 1.2 and 1.4 indicating an interested in observing and learning about nature. High score on item 2.4 may indicate an awareness of importance of protecting species against extinction. However, statements related to scientific understanding scored lower than those related to an interest in nature. Additionally, some statements (4.4, 3.6, 3.3) showed increased agreement among students, but the significance of this increase remains uncertain.

Students' feedback was positive, expressing enjoyment in learning about new species, increased awareness of their surroundings, and positive aspect of fast feedback on identifications. Some encountered issues with signing-up, uncertainty in organism identification, and difficulties photographing small, fast insects. Rain limited activity days. Students suggested having a prior familiarization activity with the application would be beneficial for a more quality execution. Students' survey responses were generally high, but due to the small sample size, we can't draw significant conclusions yet.

Students recorded on average 35.45 (*SD*=9.42) observations and average 24.77 (*SD*=11.288) species. Altogether in one month, students collected 870 observations, spanning 375 species. Since the conclusion of the activity, 8 students out of 26 (30.77%) continued using the app (collecting 504 observations, or 371 species from June until November of 2023)

Conclusions:
Most students had a positive response to the activity, demonstrating an increased interest in and awareness of their surroundings. This encouraged us to implement more of such activities into our curriculum. In the spring of 2024, another such activity is planned, which will enable us a bigger sample of students, statistical analysis, and firmer research conclusions. Students' feedback was also of great help, as it can be utilised to improve further activities and by collecting data assess the quality of changes introduced. Good feedback was also the number of students, who continued using the application, as it was not obligatory.

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Equal educational opportunities and inclusion as cross-cutting themes in biology teacher education

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Theoretical background or rationale
With the ratification of the UN Convention on the Rights of Persons with Disabilities in 2009, the design of inclusive subject teaching in Germany has become the responsibility of all teachers. They must address the increased heterogeneity in schools, particularly considering marginalised groups (Ferreira González et al., 2018). This also brings questions of educational justice (Kayumova & Dou, 2022) and resource-oriented approaches to addressing heterogeneity in biology education to the forefront (Fränkel, 2021).
In Germany, initial recommendations by the Standing Conference of the Ministers of Education and Cultural Affairs (KMK) in 2008 were further elaborated in 2015 in conjunction with the German Rectors' Conference (HRK), along with a schedule for implementation: Universities are expected to provide an inclusive overall concept by 2025 (KMK & HRK, 2015). The Teacher Education Admission Ordinance (LZV) for North Rhine-Westphalia requires a minimum of five ECTS-points for inclusion-oriented issues in subject-matter teacher education programs. Other German federal states also formulate similar requirements with varying scopes regarding so-called "inclusion credits".
The integration of these credits raises questions about how they are actually implemented in teaching (Frohn & Moser, 2021). Typically, existing teaching content is often rebranded without actual modification. This issue also applies to biology didactic programs, as indicated by a recent analysis of module handbooks (Fränkel et al., 2022).
Designing inclusive biology education requires a combination of inclusive pedagogical knowledge with content knowledge and pedagogical content knowledge for which a basic knowledge of inclusive education is considered insufficient. The aim of inclusive subject- matter training is to empower prospective teachers to plan, conduct, and assess biology classes inclusively, based on the requirements of the KMK (2008). Several approaches have been developed in recent years (e.g., Basten et al., 2021; Heuckmann et al., 2021; Schaller & Ewig, 2023) addressing many facets of inclusive biology teaching (for an overview, see Großmann et al., 2022). However, these approaches do not provide a comprehensive picture and have not yet been systematically integrated into university teaching.

Key objectives
The contribution aims to present the "BInQ-Bio" project (German: Bildungsgerechtigkeit und Inklusion als Querschnittsaufgabe im Biologie-Lehramtsstudium) as response to the rationale. The project intends to develop open educational resources (OER) to embed the topics of educational justice and inclusion as cross-cutting themes in biology teacher education, aligning with the legally mandated didactic "inclusion credits". The project is funded by the Ministry of Culture and Science of the state of North Rhine-Westphalia from September 2023 to August 2025. During this period, six accessible, digital learning modules will be developed, offering up to 14 credit points and flexible use in a modular system.

Design and methodology
The learning modules will be implemented as H5P-learning units that can be integrated into Moodle/ILIAS-based learning management systems, making them accessible to teacher education programs at all German universities. The content will be designed following a didactic five-step process based on specific learning objectives (KMK, 2008): 1. activation of existing knowledge/motivation phase, 2. conveyance of new knowledge, 3. application of knowledge, 4. assessment of knowledge growth (online self-assessment), 5. transfer/reflection task. The modules will have broad applicability as self-paced courses and as inverted classroom/blended learning sequences in university courses.
The diversity of students is taken into account through the adaptivity of the content and its accessibility, e.g. through subtitling, sign-language interpretation or text-to-speech function. The learning modules serve a dual didactic purpose: they are aimed at students working with diverse learner populations in the

future, and they also provide an opportunity for university lecturers to engage with the topic of inclusion in science education.
The project's quality is ensured through collaboration with various stakeholders, including students, internal institutions, experts from the school field and the scientific community, who will be involved in the development and evaluation of the OERs.

Results
This presentation will provide an overview of the project, the overarching concept, and the evaluation of the OER materials. By the time of the conference first concepts of specific learning modules can be introduced and discussed with an international audience.

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Experiencing flow despite disgust during dissection in biology lessons

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Fostering understanding and application of knowledge – an evaluation of biology-specific support measures

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Theoretical background or rationale
Especially in the introductory phase of science courses, subject-specific knowledge is relevant for academic success (Dochy et al., 2001). Depending on the field of study, certain knowledge types have been shown to have different effects on students' academic achievements. For biology students, the *Knowledge of Meaning* (KoM) is a predictor of academic success (Binder et al., 2019). This declarative type of knowledge includes the ability to recognize the meaning of a concept (Hailikari et al., 2007). For physics students, additionally, *Application of Knowledge* (AoK) is relevant (Binder et al., 2019). AoK means applying knowledge to explain subject-specific phenomena and to solve problems (Hailikari et al., 2007). To support beginners adequately, measures are needed addressing specific types of knowledge. Relevant information about new developed leaning measures can be derived from learners' perception of interestingness (Renninger & Hidi, 2016) and the cognitive load (Schmeck et al., 2015).

Key objectives:
The overarching aim of the study is to enhance first-year biology students' knowledge types; KoM and AoK. Therefore, the learning environments should be tested for practicability. To achieve this, we address the question of how first-year biology students perceive the developed learning environments in terms of interestingness and cognitive load.

Research design and methodology:
In the first step, the different learning environments were developed on a theoretical basis: To support KoM, *Concept Maps* are utilized. We used a set of fifteen learning materials for KoM aiming to establish an understanding of biological concepts, e. g. compartmentation, mutation, symbiosis. Oser's basic model of conceptual building (Oser & Baeriswyl, 2001) is used for the structural design of the learning materials. To support AoK, *Worked Examples* are used. The AoK learning environment consists of a total of twenty-one learning materials. Each presents a specific biological phenomenon which is explained step by step using an overarching biological concept, e. g. surface enlargement in the small intestine. Friege's (2001) model of knowledge- centered problem solving is used to structure the Worked Examples. All learning materials address cell biology as well as botany and zoology. In addition, they have a specific *fading* that is designed to help develop KoM respectively AoK progressively.
We conducted a pilot study for both learning environments with *N*=24 first-year biology students. They were randomly divided into two groups, one for each knowledge type. The students learned with the particular subject- and knowledge-type-specific learning material (see above) in a total of six, typically 90-minute-long sessions. After working with each learning material, students were asked about perceived interest, invested mental effort and perceived task difficulty using a seven-point rating scale (Schmeck et al., 2015). Furthermore, we assessed the learning gains using the tests developed by Binder et al. (2019) in a pre-posttest-design. We
used Mann–Whitney u tests to compare the dependent variables for the two groups and pairwise Wilcoxon tests to prove learning gains.

Findings:
On average, the Worked Examples for promoting AoK (*Mdn*=6) were rated slightly more interesting than the Concept Maps for promoting KoM (*Mdn*=5), *U*=53.50, *z*=-3.61, *p*<.001, *r*=-.60). For both, Worked Examples (*Mdn*=2) and Concept Maps (*Mdn*=1), perceived task difficulty was low, *U*=151.50, *z*=-.21, *p*=.833, *r*=-.04. Also, the mental effort in processing the Concept Maps (*Mdn*=2) and Worked Examples (*Mdn*=3) was similarly low to medium, *U*=106.00, *z*=-1.81, *p* =.071, *r*=-.30.
In the group that used the Concept Maps, the percentage of correct KoM solutions increased significantly after working through the materials (Mdn_{pre}=26.11, Mdn_{post}=57.50, *T*=55.00, *p*=.005, *r*=.63). Just like the group, that did the Worked Examples (Mdn_{pre}=30.28, Mdn_{post}=45.00, *T*=64.00, *p*=.006, *r*=.62). The

percentage of correct AoK solutions increased significantly after working with Concept Maps (*Mdnpre*=50.00, *Mdnpost*=62.00, *T*=26.50, *p*=.034, *r*=.47) and even more significantly when editing Worked Examples (*Mdnpre*=33.33, *Mdnpost*=83.33, *T*=55.00, *p*=.005, *r*=.60).

Conclusions:
Because the dropout rates of natural science students at German universities are above average, supporting academic achievement is particularly important. The learning environments described above could be a starting point to support academic success as it has been shown that the subject-specific knowledge types were enhanced. As these are initially perceived as equally easy to understand we assume a successful comparative design and an adequate fading. The overall high level of interest is probably an indicator for acceptance and motivation to learn (Renninger & Hidi, 2016). Based on this pilot findings, the learning environments can now be fine-tuned. Since the learning environments seem to be effective and easy to use, they will be used in a larger intervention study. In the future they could serve in supporting first-year biology students and decrease dropout rates.

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Immersive, Augmented, and Real Heart Models: Initial Results on Cognitive Load and Its Relationship With Learning Gains

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Theoretical background:
While immersive virtual reality is seen as having particular potential for visualizing complex and abstract processes in education (Matovu et al., 2023), current studies show that the use of digital media in general has so far only been designed to activate learners to a limited extent, as they are mostly used as presentation media (Kramer et al., 2019; Nerdel & Kotzebue, 2020). The human cardiovascular system also represents a subject area that is difficult to experience, as most often only indirect experiences are possible.

Key objectives:
The present study assessed the possibility of learning about human heart anatomy using virtual, augmented, or real models using the theoretical framework of cognitive load which differentiates intrinsic (ICL), extraneous (ECL) and germane cognitive load (GCL; Sweller et al., 1998, 2019). Makransky et al. (2019) previously showed in their study that less learning occurred when learning in a virtual learning lab on HMD compared to a desktop version at a higher cognitive load. Based on these theoretical foundations, this paper explores the following questions:

***RQ1*:** Is there a difference in learning about human heart anatomy between immersive, real, and AR models?
RQ2: Is there a relationship between learners' cognitive load while working with the different models and learning gains?

Research design and methodology:
To address these questions, a quantitative comparative study was designed to compare three groups based on Milgram et al. (1995) RV continuum: a group with a model in reality (real model), an AR model on a tablet, and an IVR model on a HMD (Figure 1). Learners were randomly assigned to groups by drawing a card from an opaque bag and their data were anonymized. Students from six ninth grade classes at a high school participated, all of whom were between 14 and 16 years old (M = 14.77 years, SD = 0.54 years, N = 119). They completed a pre-test and a post-test on a tablet and worked with the corresponding model at their respective station in between. This involved answering general demographic data on prior experience and prior knowledge in the pre-test and scales for presence, knowledge and cognitive load in the post-test. To measure cognitive load, a differentiated self-report scale from Klepsch et al. (2017) was used. This makes it possible to measure the individual forms of cognitive load.

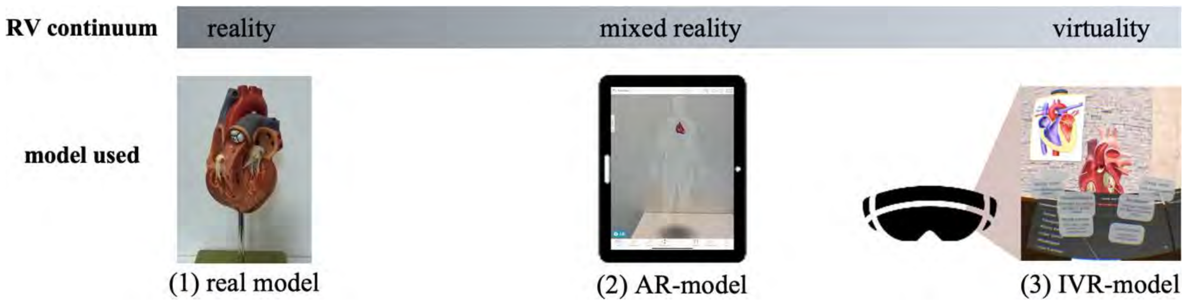

Figure 1: The models used rotted on the RV continuum according to Milgram et al. (1995).

Findings:
Figure 2 shows the averages of the variables prior knowledge, post-intervention knowledge, and learning gains broken down by the three groups. It is striking that there are significant differences between the groups only in prior knowledge (H (2) = 12.468, p < .01). Here, the difference is significant between the IVR and AR groups with medium effect size (U = 550.50, z = -3.399, p < .001, r = -.38) and significant between the IVR and real model groups with weak effect size (U = 568.50, z = -2.098, p = .036, r = -.24). The AR group had the highest learning gain (M = 3.07, SD = 2.23), while the other two groups were at similar levels.

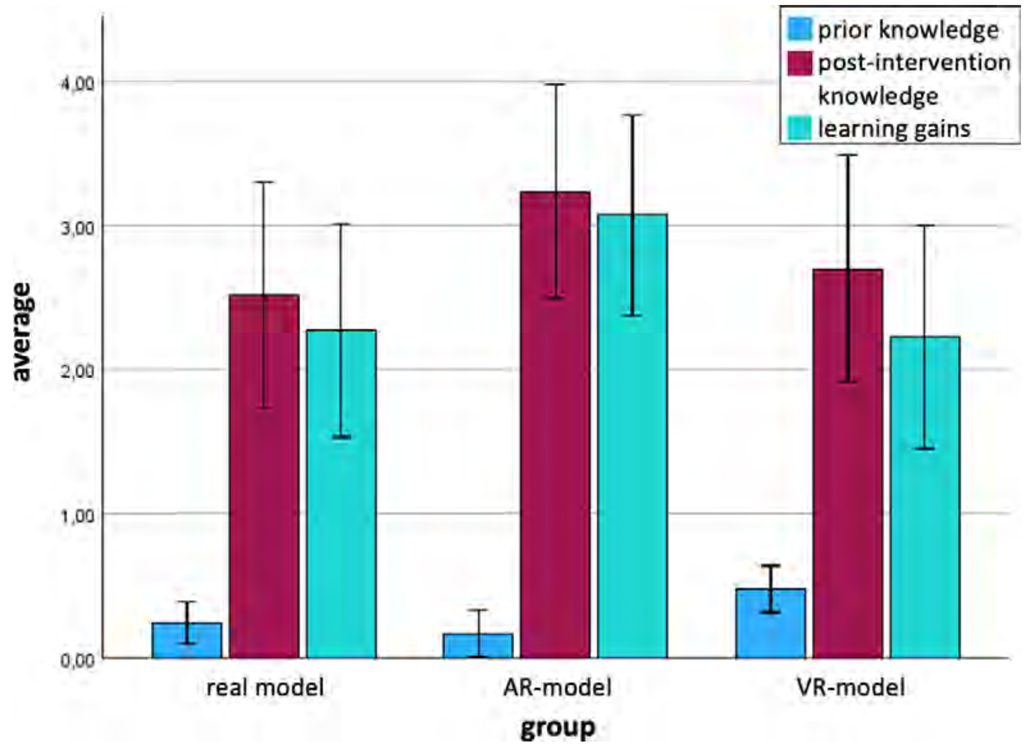

Figure 2: Averages for the variables prior knowledge, post-intervention knowledge, and learning gains.

Based on Spearman's intercorrelations, multiple linear regression was calculated to examine how cognitive load affects learning gains. The learning gain was chosen for this purpose because it has no correlation with prior knowledge. The ICL & ECL, GCL, and Tablet group variables explained 14.2% of the variance in learning gain (adj. R^2 = .142; F = 7.512; p < .001). Where the ICL & ECL is the strongest predictor as well as the only negative (β = -.318; p < .001).

Table 1: Results of the multiple linear regressions for learning gains.

variable	learning gains	
	B (SE)	***β***
constant	2.990** (.960)	-
ICL & ECL	-.648*** (.174)	-.318***
GCL	.313* (.150)	.178*
D_Tablet	.854* (.410)	.178*
***R*²**	.164	
adj. *R*²	.142	
F (df)	7.512*** (3)	

Conclusions:

The results show no significant differences in learning gains among the three groups. However, consistent with Sweller et al. (1998; 2019) CLT, the individual forms of cognitive load could be identified as predictors of learning gains. It should be noted that it was not possible to separate the ECL and ICL. Thus, the results point in the direction of those of Makransky et al. (2019). Nonetheless, the significant difference in the prior knowledge of the learners despite their random assignment need to be discussed. It is noteworthy that the learning gain is highest in the AR group, although this could not necessarily have been expected due to the lower GCL.

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Potential-oriented, gifted biology teaching: perceptions, beliefs & teacher professionalization

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Rationale
Studies impressively show that there is a need to catch up in identifying and supporting (potentially) gifted students in Germany (Vock et al., 2020). Furthermore, studies show that teachers often hold deficit-oriented views of students and their learning developments (Abels, 2019). By focusing on negative deviations from a normative notion, many students' potentials are lost (Abels, 2019). This results in challenges for schools as a whole, but also for subject- specific teaching. For science teaching, approaches such as inquiry-based learning are promising for nurturing potentials and giftedness in classrooms. However, these approaches have not yet become established in (German) classroom practice (Dorier & Garcia, 2013; Käpnick, 2022). In order to implement approaches that promote potential and giftedness in science and thereby meet the backlog demand, instructional concepts and teaching material need to be developed. In addition, a comprehensive professionalization of teachers is essential. Successful professionalization programs link to the perceptions and beliefs of teachers (Desimone, 2009).

Key objectives:
The project aimed (1) to create and test teaching material for biology instruction collaboratively with teachers and (2) to develop professionalization guidelines for teacher training. This proposal focuses on (2). The goal was to develop guidelines for teacher professionalization using the model of educational reconstruction for teacher education as a research framework (Van Dijk & Kattmann, 2007; Petchey & Niebert, 2021). The model includes three iteratively linked research tasks: systematic clarification of scientific perspectives, analysis of teachers' perceptions and beliefs, and, based on the comparison of both, the development of educational guidelines for teacher professionalization.
Oriented to these tasks, the focus was on the following research questions:
(1 & 2): What perceptions and beliefs can be identified among science teachers (1) and in scientific sources (2) about students' (scientific/biological) potentials and giftedness and how to foster them, as well as perceptions toward fostering potentials and giftedness through inquiry- based learning?
(3) Which similarities and differences become apparent when comparing the perspectives of science teachers with scientific perspectives?
(4) Which conclusions can be derived from the comparison of both perspectives for structuring and developing professionalization offers?

Research design and methodology:
Problem-centered, guided interviews were conducted to capture teachers' perspectives. The interview guide included questions about (scientific/biological) potential and giftedness, giftedness support in classroom instruction, diagnosis, as well as conceptions on fostering students' potentials through inquiry-based learning.
Interviews lasted between 54 and 144 minutes (M=107.53 min SD=23.55). The sample consisted of N=15 science teachers (12 female, 4 male, M=44, SD= 8.70, 30-60 years). Teachers had 2-39 years of professional experience (M=15.6, SD=10.03). Scientific clarification included analysis of N=21 relevant scientific sources from the fields of giftedness research, psychology, education, and science/biology education.
The interviews were transcribed and edited and, like the scientific sources, analyzed by means of a qualitative content analysis according to Mayring (2021) with MAXQDA2022.

Findings and Conclusions:
Key findings include a predominantly broad understanding of giftedness on both sides, as well as parallels concerning potential and giftedness development through inquiry-based learning. Nevertheless, both perspectives point to challenges in using inquiry-based learning. The interviewed teachers seem to predominantly have a multidimensional understanding of giftedness. However, the analysis also shows that while the dynamic character of giftedness is described in the scientific perspective (e.g., Stöger et al., 2018), the science teachers seem to hold a rather static conception of giftedness. Differences are also evident concerning inquiry- based learning: while in the scientific perspective inquiry-based learning is seen as an approach promoting scientific thinking and enabling learning about scientific methods and the nature of science (e.g., Crawford, 2007), for most teachers it represents “just” a pedagogical concept

that enables learners to work in an interest-driven way. The teachers do not seem to see the subject-specific potential of inquiry-based learning to the same extent as it is discussed scientifically. The poster will display and discuss the detailed results and implications for biology teacher training.

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Primary experiences in teacher education: Effects of multi-sensory learning environments on species knowledge of birds.

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Teach or let learn? A comparison of the learning effectiveness of teacher- and student-centred biology teaching using Mendel's rules as an example

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Rationale

The systematic reflection of teaching and learning processes and thus of the learning effectiveness of teacher- or student-centred teaching called for by the KMK (2019) is probably the exception due to the multitude of learning arrangements in everyday school life. Wilkes and Stark (2023) distinguish between cognitive and affective barriers as possible barriers to the consistent implementation of evidence-based teaching. Cognitive barriers are, for example, deficient knowledge and difficulties in assessing and applying scientific knowledge or misconceptions. An affective barrier is, for example, the lack of motivation to engage with evidence. In addition, many teachers lack the time to work in an evidence-based manner (ibid., p. 291 f).

The learning effectiveness of cooperative forms of learning in groups, in which learners want to achieve common goals, has long been very well documented (cf. Johnson et al. 2000, p. 1; Johnson & Johnson 1999 pp. 68, 73). Hattie (2013, p. 251) gives an effect size from 10 meta-analyses of 0.41 for this shared form of learning. But how successfully do students learn in groups that can but do not have to work together, so- called "traditional classroom learning groups" (Johnson & Johnson 1999, p. 68), i.e. that have the same learning goal but are not "forced" to cooperate?

In summary: 1. teachers often lack the time and opportunity to make a research-based decision for teacher- or student-centred instruction. 2. there is a lack of evidence-based data on the learning effectiveness of teacher- or student-centred teaching in the different social forms.

Key objectives

Against this background, it is investigated how different social forms affect the subject competence of pupils.

Research question I: "Does the short-term learning effectiveness of group work differ significantly in comparison to teacher-centred teaching using the example of subject competence with requirement area I in the topic of Mendel's rules?

Research question II: "Does the long-term learning effectiveness of group work differ significantly in comparison to teacher-centred teaching, using the example of subject competence with requirement area I in the topic of Mendel's rules?

Research design and methodology

Classical genetics is taught in Mecklenburg-Western Pomerania (MV) as a school biology subject in the 9th or 10th grade. The contents include inheritance patterns according to the 1st-3rd Mendelian rule, mutation and modification as well as family trees (Rahmenplan Biologie Gymnasium 2022, p. 33 f).

The pilot study is methodologically based on a cross-over design. The sample comprises 21 pupils (drop-out: 3) in grade 10 of a Gymnasium. The pupils learned in student-centred biology lessons during test period 1 in group work with texts from the textbook Biology Today. S II (2011, p.112). In the teacher-centred biology lessons, a Microsoft Power Point supported teacher lecture was presented to the same students based on the same textbook (p.113). The scope of the lesson material and the test material were designed to be applicable in a double lesson of 90 minutes.

Measurement data was collected at three different time points: t0: control to investigate learning effectiveness and motivation to learn (pretest). t1: Short-term study (direct follow-up) of learning effectiveness after student-centred teaching in group work on the topic of Mendel I and II (t1_gw) or teacher-centred teaching on the topic of Mendel III (t1_tl).

t2: Long-term study (6 or 7 weeks) after pupil-centred teaching in group work on the topic of Mendel I and II (t2_gw) or teacher-centred teaching on the topic of Mendel III (t2_tl).

The students' factual competence was assessed with learning tests on the topic of Mendel's rules. The learning test includes tasks for subject competence in requirement area I: filling in gaps in a Punnett square or translating terms from classical genetics (=test material).

In addition, motivation to learn was assessed with the FAM questionnaire (Rheinberg, Vollmeyer, Burns 2019). The data were treated as linked samples. Due to the lack of a normal distribution according to Kolmogorov-Smirnov or Shapiro-Wilk and the lack of variance homogeneity (Levene), the data were analysed using the Friedman test. The significance level was set at $\alpha = 0.05$ (5%). The effect size was calculated as follows: $r = z/\sqrt{n}$ and interpreted using the conventions of Cohen (1988, pp. 283-287): 0.1 - 0.25 (small); 0.25 - 0.4 (medium); > 0.4 (large).

Findings

The results on the primary outcome, the average grade, show: Research question I: no significant differences in performance in the short term following student-centred teaching in group work on Mendel I and II (t1_gw: median 12 points) vs. teacher-centred teaching on Mendel III (t1_tl: median 13 points) (p:0.305). Research question II: significant differences in long-term learning effectiveness in group work (t2_gw: median 11 points) vs. teacher-centred teaching (t2_tl: median 5 points) using the example of subject competence with requirement area I on the topic of Mendel's rules (p: 0.006, see Fig. 1). The students' performance in the learning test after the group work is better in the long term with a large effect size (r=0.9) and practical relevance

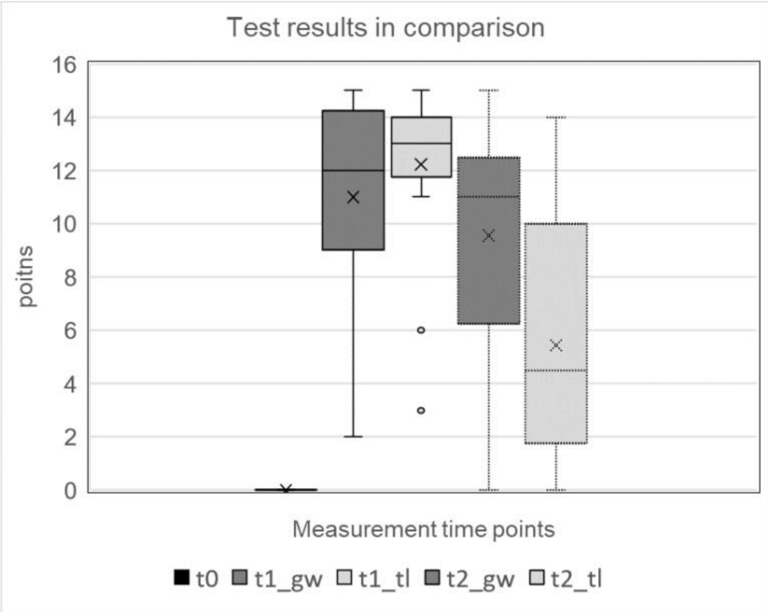

Figure 1: Achieved scores in method comparison
Explanations from left to right: t0->pretest; t1_gw-> short-term group work; t1_tl-> short-term teacher lecture; t2_gw-> long-term group work; t2_tl-> long-term teacher lecture

Discussion

The long-term learning effectiveness with group work is significantly better in this pilot study. The students achieved higher scores in the long term and thus better grades. Groups that are put together randomly, e.g. by drawing lots, and without the specification of learning objectives that can only be achieved together, can also be effective for learning.
In terms of learning effectiveness, biology lessons on the topic of Mendel's rules should therefore rather be designed in student-centred learning forms. The extent to which the results can be generalised and transferred to other topics would have to be examined on the basis of a larger sample.
The effects on learning motivation were not significant. The teacher experiences the student-centred lessons as personally more relaxed (without questionnaire survey). There is more time for feedback to the students and pedagogically significant relationship work. Presumably, this positive classroom experience also has long-term effects on teacher health.
Due to the relatively small samples (n=21, drop-out=3), the generalisation of the results is only possible with reservations. In order to be able to make clear statements about learning effectiveness, the test material was designed in such a way that only the subject competence in was only tested in requirement area I.
The results therefore only refer to this type of task.

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Teaching biology lessons supported by digital media – what is needed to transfer the knowledge to school?

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Theoretical background or rationale
Teachers' Pedagogical Content Knowledge (PCK) can be described by the Refined Consensus Model of PCK (RCM), which differentiates between different realms of teachers' PCK, visualised by three concentric circles (Carlson & Daehler, 2019). In the inner circle, the Plan- Teach-Reflect Cycle of the so-called enacted PCK, the unique PCK which is only expressed in a concrete teaching situation, is located (Alonzo et al., 2019). This Plan-Teach-Reflect Cycle refers to the three steps of teaching teachers go through: they plan their lessons, teach their lessons, reflect on relevant events within the teaching situations afterward, and feed their conclusions into future lesson planning. Thus, reflection on teaching is an essential part of teaching (Alonzo et al., 2019). To enable reflection processes, teachers' professional vision is essential: relevant events for students' learning need to be noticed in the first step (Sherin, 2007), and to be reflected on the basis of PCK in the second step, whereby the noticed event is described, and explained by referring to PCK, followed by proposing alternative teaching strategies (Seidel et al., 2010; Seidel & Stürmer, 2014; van Es & Sherin, 2002). Professional vision can be trained by using video vignettes (Santagata & Guarino, 2011; Stürmer & Seidel, 2015), whereby expert and peer feedback increase professional vision stronger than self- reflection only (Weber et al., 2018).
In the framework of a joint project, video vignettes are created that show the sensible use of digital media in biology lessons to support the implementation of biology-specific lesson quality features such as cognitive activation and conceptual understanding (Neuhaus, 2021), based on DigCompEdu (Redecker, 2017), a European framework for teachers' digital competences. Thereby, short scripted teaching situations are designed to focus on the intended lesson quality features only.

Key objectives:
We aim to support teachers' reflection on biology-specific lesson quality features and on the use of digital media, and to provide ideas for participants' own lesson planning.

Research design and methodology:
To answer the research questions "What do trainee/in-service teachers need in order to (1) further develop their own biology lessons with the help of digital media, (2) successfully give peer feedback on lesson observations, and (3) successfully transfer these skills into the school community?", a one-group study is to be done. The intervention includes a two-part teacher training session: in the first part, the described video vignettes are to be used as a basis for structured theory-based joint reflections using an observation file focussing biology-specific lesson quality features (Behling et al., 2022a), which should contribute to the increase of participants' PCK (Behling et al., 2022b), encourage and enable teachers to implement peer feedback on lesson observations as well as reflections on their own teaching, and feed into participants' future lesson planning and teaching. To consolidate the resulting experiences,
participants reflect on their own teaching and observation experiences a few weeks later in the second part of the teacher training session. About one year after the intervention, interviews with the participants as well as with the respective headmasters are conducted in order to identify on the basis of self-assessments helpful and hindering conditions for the transfer of components of the intervention into individual lesson development as well as into the school community.

Findings:
First results of a pilot study will be presented.

Conclusions:
We assume to detect some findings that will help us better support teachers to transferring their acquired knowledge from teacher training sessions to their individual lesson development as well as into the school community.

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The introduction of intersessional revision in a biology course for 1st-year university bachelors in the Wallonia-Brussels Federation was in relationship to improved results in the June exam

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Introduction

This biology course is part of the program for students of the 1st bachelor's degree in biological sciences and chemical sciences. Teaching/learning activities take place during the 1st quadrimester, from mid-September to mid-December, and include theoretical lectures, exercise and reflection sessions called study aids (Palmaers and Thiry, 2021), practical work, formative assessments… In the Wallonia-Brussels Federation, three exam sessions are organized for 1st bachelor students: January, June and August/September. However, there was no learning support for students who failed the January exam during the 2nd quadrimester in this course.

Since the Sars Cov-2 pandemic, the success rate for the January exam has dropped significantly. We therefore introduced four intersessional revisions (Perret et al., 2014) in May 2022 and May 2023 to support student learning before the June exam.

The aims of this preliminary study are to assess student participation in the system and to determine whether a relationship exists between participation in intersessional revisions and improved results on the June exam.

Material and methods

Intersession revisions are intended for all students who have failed the January exam for this biology course (final mark below 10/20), voluntarily. Four major themes of the course, often posing difficulties for students, are addressed, each in a 2-hour face-to-face session. Prior registration is required, and students can choose from 1 to 4 themes. Groups of 25 to 30 students are created and, depending on the number of students registered, each theme is organized twice.

As with study aids, revision sessions require the active participation of students (De Clercq et al., 2022). The teacher, an assistant and/or the professor, begins with a theoretical background including oral questions, then the students work on exercises, alone or in small groups. The teacher interacts with the students, enabling proactive, interactive and retroactive regulations (Wiliam and Thompson, 2008). On several occasions, the exercises are corrected collectively, with the active participation of the students. An important part of these revisions is devoted to identifying and analyzing students' difficulties and errors, as well as identifying and clarifying expectations. Intersessional revisions are therefore complementary to the teaching/learning activities organized during the 1st quadrimester.

Data comes from attendance records taken at each session, June exam results and an inquiry submitted to students at their group's last session in 2023 in the form of an online questionnaire.

Results

The number of students who participated in at least one revision was 95 in 2022 and 75 in 2023. The participation rate, calculated on the basis of the number of students who presented the June exam and participated in at least one revision compared to the total number of students who presented the June exam, was 67.6% in 2022 and 61.2% in 2023.

The absence rate (registered students absent from the revision) was between 15.7 and 21.8% in 2022 and between 1.4 and 14.6% in 2023, depending on the theme.

The success rate is higher for students who have attended at least one revision than for those who have not, with an increase of 7.44% in 2022 and 5.73% in 2023. However, this difference is not statistically significant (χ^2 test).

The average score obtained in June by students who attended at least one revision was higher than the average score of students who did not attend a revision session, and this was significant at the 10% threshold in 2022, with an increase in average score of 0.86/20 points (Student's t test, p value = 0.067), and at the 5% threshold in 2023, with an increase between the two groups of 1.06/20 points (Student's t test, p value = 0.037).

The revision inquiry was completed in 2023, with 67% of students taking part in at least one revision. The results were very positive, with for example 97.8% of students stating that they thought their success chances for an exam question on the topics covered had increased after the revision sessions (57.78% "agreed" and 40% "strongly agreed" with the statement).

Discussion and conclusion

The results are very encouraging, both in terms of student participation and significant increase in the June exam average of students who attended at least one revision. However, there are some limitations. The choice of whether or not to participate in revisions can be an indicator of engagement, and students' level of engagement influences academic success (Dupont et al., 2015). In addition, the exercise statements were available to all students on the course's intranet platform and the corrections were shared on social networks, which may have helped to some extent students who did not participate in the revisions.

The significant increase in the average score obtained in June by students who participated in at least one revision, accompanied by a non-significant increase in the success rate among these students, could be explained by the fact that the four themes addressed during the revisions do not fully cover the course material. Further analysis is required to confirm this hypothesis.

The results presented here demonstrate the value of organizing intersessional revisions for a course that takes place in the first quadrimester, and encourage us to continue with these revisions and the evaluation of their effectiveness in future years.

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The school garden in the eyes of primary school teachers

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Theoretical background or rationale
School gardens can be a valuable environment for science education that stimulates students' interest and motivation to learn (Eugenio-Gozalbo et al., 2019), helps connect abstract learning with hands-on learning, and develops observational skills (Eugenio-Gozalbo et al., 2020). Research also suggests positive changes in students' academic achievement (Blair, 2009; Morgan et al., 2010), attitudes toward the environment (Lautenschlager & Smith, 2008), and dietary behaviours (Blair, 2009; Morgan et al., 2010). School gardens allow students to have outdoor experiences, provide opportunities for physical activity (Howarth et al., 2020), and improve their mental well-being (Howarth et al., 2020). However, Højgaard Christensen and Wistoft (2019) reviewed experimental studies of the effectiveness of school garden education programmes in mathematics, languages, and science and found that they are sometimes less effective than more traditional instruction in those subjects.
Therefore, further studies are needed to optimise the role of school gardens in education. Gardening will only be possible if kindergarten or school teachers have the necessary skills for these types of practices (Pogačnik et al., 2012; Bergan et al., 2023). Strgar (2007) argue that a teacher who demonstrates an appropriate understanding of and interest in plants can make students understand that plants are intrinsically interesting. This makes teachers a main target group of this study.

Key objectives:
The research objective was to determine the interest of Slovenian teachers in plants, their attitudes toward ecosystem services provided by school gardens, and possible correlations between teachers' interest in plants and their perceptions of school garden ecosystem services.

Research design and methodology:
Sample
Our sample consisted of 132 in-service teachers from primary schools in Slovenia. Participation in the study was voluntary and anonymous. Based on the knowledge of the population and the purpose of the study, a purposive sampling technique was used.

Instrument and method
In September and October 2018, teachers completed an online questionnaire designed for this study. It included some basic descriptive variables. Next, the teachers answered closed questions about their views and experiences with school gardens, followed by fifteen items about their interest for plants (IP) (using the 5-point Likert scale: 1 = completely disagree to 5 = completely agree), and eighteen items about ecosystem services of school gardens (ESSG) (using the same scale).

Data analysis
Basic descriptive statistics of attributive and numerical variables were employed. The quantitative data met the assumptions that are required for the use the Pearson correlation coefficient. The sixteen items of teachers' attitudes toward ecosystem services of school gardens (ESSG) were subjected to principal component analysis (PCA) with Oblimin rotation. The Kaiser–Meyer–Olkin value was .877, exceeding the recommended value of .60, and Bartlett's test of sphericity reached statistical significance (χ^2=915.40, df=198, p<.001), supporting the factorability of the correlation matrix. The scree plot supported four components for further investigation. Two items were dropped from the analysis due to factor loadings bellow .35 and due to cross-loadings. The four factors obtained explained 69% of the total variance.

Findings:
On average, respondents showed high interest in plants (IP) (M=4.2, SD=.5) (Fig.1). They also showed positive attitudes toward the ecosystem services of the school garden (ESSG) for education (M= 4.3, SD = .6), relaxation and enjoyment (M=4.0, SD=.7), habitat and regulatory services (M=3.9, SD=.7), and finally plant cultivation (M=3.7, SD=.7) (Fig.2). Correlations between all measured ESSGs and IP variables are statistically significant. This means that teachers' interest in plants positively correlates with their attitudes towards the ecosystem services provided by the school garden (Tab.1).

Figure 1. Teachers' interest in plants (IP).

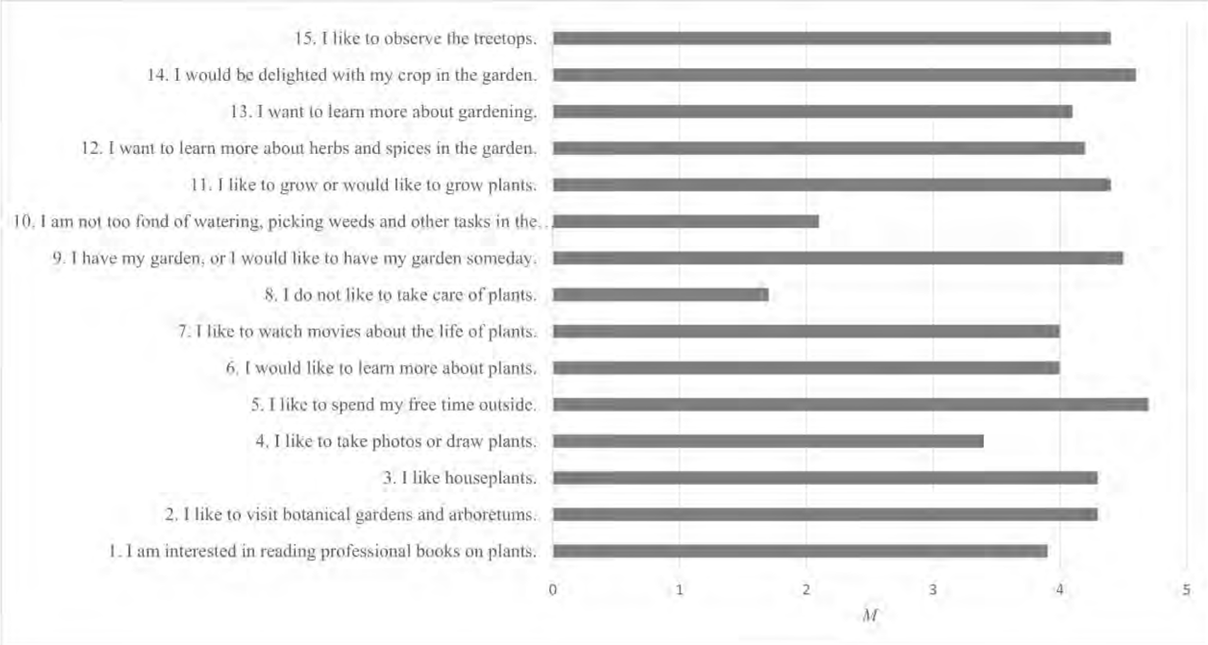

Figure 2. Ecosystem services of school garden (ESSG).

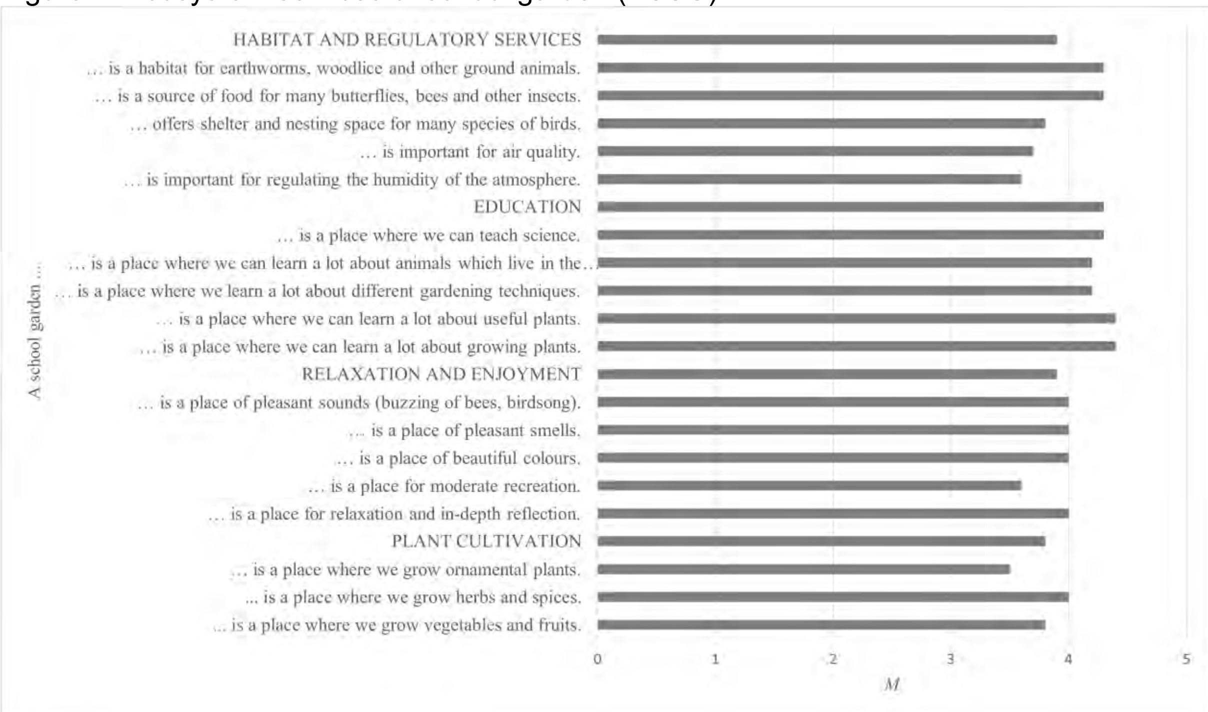

Table 1. Correlations between ESSGs and IP.

	IP	ESSG:education	ESSG:relaxation and enjoyment	ESSG:plant cultivation
ESSG:education	.231*			
ESSG:relaxation and enjoyment	.209*	.467*		
ESSG:plant cultivation	.346*	.438*	.432*	
ESSG:habitat and regulatory services	.271*	.495*	.551*	.372*

*p=.001

Conclusions:

Our results indicate that Slovenian primary school teachers are aware of the importance of the school garden in education. It is now important to create systematically the conditions in the education system that would enable all Slovenian schools to have school gardens and use them effectively. Limitations of this study are the sample size and sampling, where respondents voluntarily participated in the study.

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The transferability and adaptivity of an online exchange lesson in science education – a case study

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THEORETICAL BACKGROUND AND RATIONALE

The ICSE Academy (European collaboration and mobility in professional development of pre- and in-service STEM teachers (proSTEM)) is a partnership of 13 Higher Education Institutions, 13 policy-making organizations and over 50 schools in 13 European countries to provide innovations for professional learning of pre- and in-service STEM teachers. These innovations contribute to closing the gaps between – on the one side – the need of (in- and pre-service) STEM teachers when it comes to professional development, and – on the other side – available professional learning opportunities.
ICSE Academy offers a wide range of activity formats, e.g., summer schools,
clustered workshop series and reflective job-shadowing for teacher educators and teachers in biology, chemistry, physics, engineering, mathematics, and STEM in general. Jointly organized by all project countries and taking place across Europe, each format provides an enriching European perspective on STEM education, supported by a distinct spotlight on learning about, from and for each other. This study is based on one of the job shadowing sessions that was carried out in Norway, and observed by partners from Lithuania, Sweden, and Turkey. Most of the pre- service teachers taking part in the course had biology as a teaching subject.

KEY OBJECTIVES

The purpose of the ICSE Academy project is to develop a status quo on mobility and the European dimension and priorities in terms of STEM teaching and learning, to evaluate the impact of pro-STEM virtual and real mobility on participant teachers, and to evaluate the quality/relevance of the cooperation among pro-STEM partners.
This study seeks to add to this purpose by evaluating to what extent an individual regional activity is transferable to different contexts. The activity is a 90-minutes online exchange activity with the topic inquiry-based learning. The guiding research questions are: (1) To what extent are the individual regional activities effective and accessible? and (2) To what extent are the regional activities transferable to different contexts?

RESEARCH DESIGN AND METHODOLOGY

The study aims to provide detailed evaluation of a 90-minutes online exchange course. Such a detailed evaluation requires the employment of a case study approach (Yin, 2017). The case concerns the participants of the exchange course, and consists of a lecturer from Norway, local students at the University that are
present in-person, and both local and international online participants. The empirical material consists of multiple sources of data to capture a better picture of the case Rashid et al., 2019). These are three semi-structured interviews with pre-service teachers participating in the professional development course, observations, and reflection notes from three external teacher educators from different countries attending the session and of the lecturer presenting the session under observation, in addition to documentation related to the session, such as a plan and tasks for group work. Data are inductively analyzed according to the principles of reflexive thematic analysis (Braun & Clarke, 2021), and with consideration of the research questions. This approach was chosen as it enabled the identification of patterns across our entire data set, while also allowing informed interpretation of the data.

FINDINGS AND CONCLUSIONS

Our preliminary findings indicate that the participants on the course found the topic relevant to their own teaching in different countries. The topic of the course, inquiry- based learning with a focus on the importance of discourse for an exploratory learning environment, was recognized as central to a teachers' teaching skill, in addition to highlighting several teaching strategies that is valuable for implementing the topic to students.
Findings also indicate that the observers from the other countries chose this lesson as they were familiar with the topic and saw it as relevant for their own teaching. The relevance of the topic was, among other

things, explained by its not context-based nature, but universal relevance. In that way, online exchange courses can be valuable for getting inspiration for their own teaching. The lesson was evaluated as both transferable and adaptive to other contexts, in addition to functioning as a starting point for further developing the lesson.

The online exchange course was evaluated as valuable as it opened for participants from different countries to share their ideas and thoughts on the topic at hand.

Through participating in online courses in an established network, teachers access ideas and professional materials from around the world (Filippi & Agarwal, 2017). As the lesson in this study was primarily conducted in English, the participants did not experience severe language barriers when following the lesson. However, the online viewers were not able to attend and observe the pre-service students group discussions, as these were conducted in their own language. This indicates that such courses should be attentive to problems related to language.

Our preliminary findings suggest that online exchange courses are important tools for exchanging teaching ideas and perspectives between countries, and that lessons conducted within a specific context is seen as transferable and adaptable to other contexts, if the topic is universal and central for teachers' teaching skills.

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Undergraduate bioscience students studying their peers: biology education research projects at a research-intensive university biosciences department.

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Theoretical background or rationale

In 2018, the results of a 4-year study conducted jointly by the UK's leading science and humanities academies (The Royal Society and the British Academy) was published on the status and future directions and needs of educational research (Harnessing Educational Research, 2018). One major recommendation from that report centred on the need for an increase in the pipeline of researchers in the education research field owing to the current age demographic of UK education researchers. A second major recommendation from the report was a call for the promotion of interdisciplinary collaboration, particularly between disciplinary experts and education researchers. To address these recommendations, we sought ways to increase the collaboration between Biology Education Researchers and Bioscience subject researchers and to introduce the principles of Biology Education research to a new generation of Bioscientist.

Key objectives:

One way of achieving an increase in Biology Education research activity was to encourage Bioscience undergraduate students to conduct research in Biology education, particularly within their home department. We therefore designed a final year undergraduate education research project module for a large Biomedical Sciences degree at one of the UK's most research-intensive universities. This module was launched in 2018 and represents over one- third of an undergraduate student's final year grade and has exact parity in terms of weighting and assessment with the laboratory research project modules conducted in the same department. Students taking this module are encouraged and supported to design a research project of their choice based on their interests within Biology education. They are allocated two supervisors, one disciplinary Biomedical Sciences researcher and one disciplinary education researcher. Rather than the lab-based work that would take place, the students design their own biology education research project studying Biosciences education within their home University.

The key objectives of this research was to determine:

1. **What are the common areas of educational interest for biology undergraduates to carry out their research in?**
2. **How do students build on the previous findings from other dissertations?**
3. **The extent to which the implications suggested from the findings could inform the education objectives for the bioscience department.**

Research design and methodology:

By the time of the talk, 18 projects will have been completed over a five-year period, which encompasses one-year pre-Covid-19-pandemic to the current academic year. This research aimed to analyse using a thematic analysis these research dissertations based on their i. methodological approach and participants involved, ii. theoretical framework(s) used, iii.
findings, iv. suggested implications. Where findings were built on previous dissertations, analysis was carried out to find out the extent to which these findings supported one another and the differences between them. We will also interview a selection of students who have completed their project to further understand their motivation for project design and theoretical frameworks involved.

Findings:
Whilst analysis is still underway, the initial findings have shown the most common areas of research for these undergraduates have been in:

- Online teaching (caused by the pandemic)
- Student engagement and motivation
- Student aspirations and Science capital
- Student transition from secondary to tertiary education

The choice of dissertations suggest that students choose to research areas that look to improve students experience and come from a social justice perspective when engaging in educational research. This is reflected in the theories adopted for the dissertations, such as student agency (Arnold and Clarke, 2014), critical pedagogy (Galamba and Gandolfi, 2023) and science capital (Archer et al. 2015) rather than in conceptual change research. Research was mostly mixed- methods, with the implement of a survey and interviews, although the data shows that students have a preference over quantitative methods.

Conclusions:
Undergraduate students are more than capable of undertaking high-quality Biology education research projects embedded in a rigorous theoretical framework, particularly when quantitative data are collected and analysed. They can, therefore, act as agents for change in expansion of interdisciplinary approaches to Biology education research. The chosen project aims of biology undergraduate students shows promise in both the development of their own skills beyond their scientific skills, and in their engagement with social research that has real implications for future students learning in the department. The build-up of data over the years on exploring students' motivation tells a particularly novel narrative that reflects the students experiences of learning in a pre-and post-pandemic environment. Such a co-construction of insights and perspectives into this department will continue with a particular focus on supporting students to develop their qualitative skills. Additionally, the results of this study have already resulted in more Bioscience staff members becoming interested in supervising Biology education research projects and we shall focus on further expansion of the biology education research endeavour in the department.

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Using simulation-based learning environments to support mathematical modelling in biochemical settings

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5

Using student feedback in developing successful teaching strategies for biology teachers in a dynamic teaching environment

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Theoretical background:
In the field of science education and science education research, a broad consensus about teaching quality standards emerges (Praetorius et al. `20) with domains like cognitive activity, constructive support, classroom management (Hattie `09). Yet, there is the problem of implementation, and the question as to how to broker the theory practice gap. (Shavelson `20).
Teaching is taking place in a dynamic environment (Hattie `09), where multiple interrelated variables have their idiosyncratic and everchaning effects on teaching outcome (Irmer `23). Thus, teaching success is a probability game, where teachers make gut feeling decisions in the spirit of decicion making under uncertainty (Kaneman & Tversky `74).

Although as professionals, teachers have access to pedagogical content knowledge, and domain- specific collective pedagogical content knowledge (Carlson & Daehler `19), they often fail to use empirically proven methods or interventions (Shavelson`20).
Instead, they use habits partially unreflected or fail to articulate didactical justifications for their teaching strategies (Shavelson `20). Thus, focus has shifted towards research as to how to improve enacted pedagogical content knowledge of teachers (Irmer`23)
At the centre of the refined consesus model (Carlson & Daehler `19) the dynamic structure of teaching is reflected by a rinse and repeat cyle. Executing this plan teach reflect cycle in different timeframes is the essence of a teachers enacted pedagogical content knowledge (Irmer`23).
Teachers using this cycle mirroring a scientific rinse and repeat cycle enhance their teaching methods and teaching quality over time. (Altrichter `18).

But reflection of one's teaching practices during the different cycle stages does not occur spontaneous and needs a catalyst to take place (Shavelson `20). A feasable way of getting a reliable estimate of, and thus trigger reflection when needed, is via student feedback (Wisniewski´20).
Key objectives:
The aim of this research project was help teachers improve their teaching methods via a rinse and repeat cycle, based upon a student-feedback-loop.

Research questions:
RQ1: Does the use of a visual feedback trigger reflection of teaching methods?
RQ2: Which of two visual feedback options triggers reflection of teaching methods more?
RQ3: Does the integration of visual feedback into a rinse and repeat cycle lead to enhanced teaching quality over time?
RQ4: Which of two visual feedback options leads to a stronger enhancement of teaching quality over time?

Research design and methodology:
A total of 27 teachers with 33 classes and 650 pupils of biology and science classes took part in the study within an incomplete 3x1 framework. In our study, student feedback was collected for five consecutive weeks after each lesson via a digital tool and deployed to the teachers on the *teachertunes.de* website. As dependent variables, two differing visual variants were displayed to biology teachers and compared to a control group with no visual clue about the student feedback.

The following conditions were met: no visual feedback, performance curve feedback, variance curve feedback. As dependent variable, the student feedback was collected. A linear mixed model was used to investigate the development of teaching quality over time. T-tests were used to test differences between the two visual variants and the control group. Qualitative data was collected in the middle of the study and immediately after the study with an open-ended questionnaire to assess the contribution of the visual displays on the reflexivity of the participating teachers.

Results:
Quantitative analysis:
In the mixed linear model, there is evidence of a significant effect for the performance curve, but no proof. The p-value is 0.1 (estimate=0.12, t=1.373, SD=0.08). The model predicts, that a biology teacher using the performance curve between two consecutive lessons in the same class, will have a higher mean rating of 0.12 in the second lesson by a margin of 0.12.
A Welch two sample t-Test shows, that the visual performance display leads to significant higher performance ratings than the visual variance display ($p<0.01$, $t=2.669$, $df=73.3$).
Qualitative analysis:
Concerning the performance curve, 50% of the teachers found the visualisation very useful to reflect their lessons. Concerning the variance curve, a majority of participants found the visualisation too complicated to be implemented into everyday school life.

Conclusions:
The finding, that the more simple performance display leads to a better performance rating than the visual variance display suggests that a simple tool can be successfully integrated into the plan teach reflect cycle. Our quantitative results indicate that student feedback facilitates reflexivity of teachers and improves enacted pedagogical content knowledge of biology teachers. Albeit there is a strong effect of the performance display on teaching performance, there is no scientific proof. We emphasize the more abstract notion of a need to implement a rinse and repeat mechanism mirroring the scientific cycle on the individual teacher and lesson level to overcome old habits and render reflection processes possible.

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What do in-service teachers understand by scientific skills and which ones do they promote in their classrooms?

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Introduction

Nowadays, the science education community agrees that science learning should focus on how to do science, rather than just studying science topics (Justi & Gilbert, 2003). This implies a shift from the stress on acquiring conceptual concepts to the importance of knowing how science is generated and validated (Lederman et al., 2013). To do so, students should address meaningful questions to acquire comprehensive knowledge of a given topic and understand how scientists work on it (Bárcena & Martínez-Aznar, 2022).

Teachers should design and implement approaches that encourage students to think and reason about science by asking questions, developing models, or evaluating alternative explanations (Martins-Loução et al., 2020). Most of the literature (Constantinou et al., 2018) has focused on pre-service teachers, pointing to the need to involve teachers during their training in activities that promote their scientific skills, and strategies for doing so with their future students. We believe it is also important to identify which scientific skills in-service teachers are addressing and how.

This proposal is framed in a research project focused on identifying the transitions of students' scientific skills development among educational stages and the strategies used by teachers to promote them. This work seeks to identify what in-service teachers understand by scientific skills and which ones they promote in their classrooms. The research questions (RQ) are:

1) What do in-service teachers understand by "scientific skill"?
2) What scientific skills do in-service teachers consider that they address?

Methodology

The sample consisted of 60 in-service teachers (6 pre-school, 25 primary and 29 secondary biology teachers), who responded voluntarily and anonymously to a questionnaire with four open-ended and three multiple-choice questions.

To identify the scientific skills that in-service teachers should promote, we considered those proposed by the NRC (2012), the PISA 2025 Science Framework (OECD, 2023) and the Spanish Curricula (Ministerio de Educación, 2020). Based on these, three main dimensions were established: designing scientific investigations, explaining phenomena scientifically, and using, evaluating, and communicating scientific information. Then, the specific skills included in each dimension were identified.

The responses to the questionaries were analysed. A content analysis was carried out for RQ1. A reference definition of scientific skills was developed based on the definition provided by Alake-Tuenter et al. (2012). Then, this definition was contrasted with the definition provided by the participants, identifying four categories of analysis.

For RQ2, the scientific skills included in each dimension were used as categories. Then, the frequency of each skill in the participants' responses was determined.

Results

28 participants define "scientific skill" as the ability to carry out the actions of scientific work (Figure 1). Some of them provide examples such as formulating questions, posing research hypothesis, or recording data. It is noteworthy that almost half of the sample (25) relate scientific skills to the ability to know the scientific content. Others relate scientific skills to content knowledge but recognise the importance of their application in daily life contexts (5). Despite these results, we identify a change is teachers' perception since 33 teachers relate scientific skills to the application of knowledge or the development of skills inherent to scientific work.

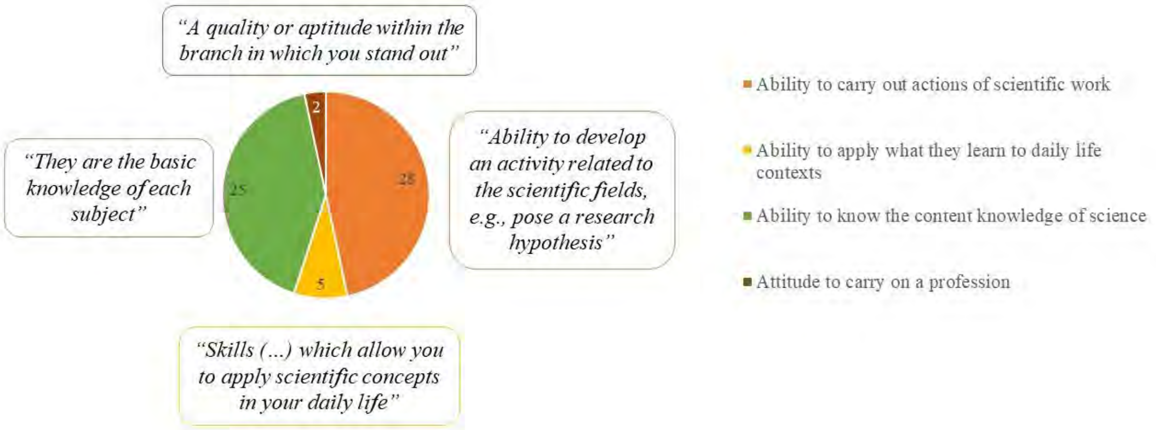

Figure 1. Results of RQ1.

For RQ2, figures 2-4 show that investigations planning is the dimension they work on most, highlighting skills related to formulating research questions. Then, teachers consider the identification of patterns. Reliability and replicability in design and errors that may occur are only mentioned by 12 teachers, most of them from Secondary Education. This is consistent with the results of Bárcena & Martínez -Aznar (2022).

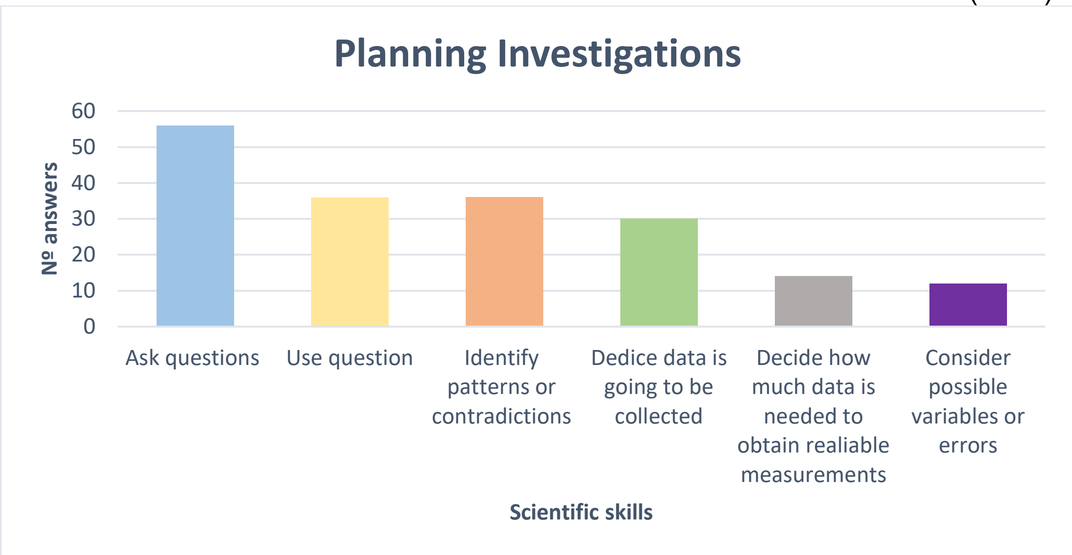

Figure 2. Frecuency of skills related to plan investigations.

Regarding the second dimension (Figure 3), the skill "providing causal explanations" predominates. Meanwhile, being able to move from one model to another or identifying their weaknesses are the least cited. Studies have shown that teachers still focus on explaining the phenomenon based on the valid model, rather than promoting the evaluation of explanations of the same phenomenon, considering different models, and identifying the most suitable one based on evidence (Justi & Gilbert, 2003).

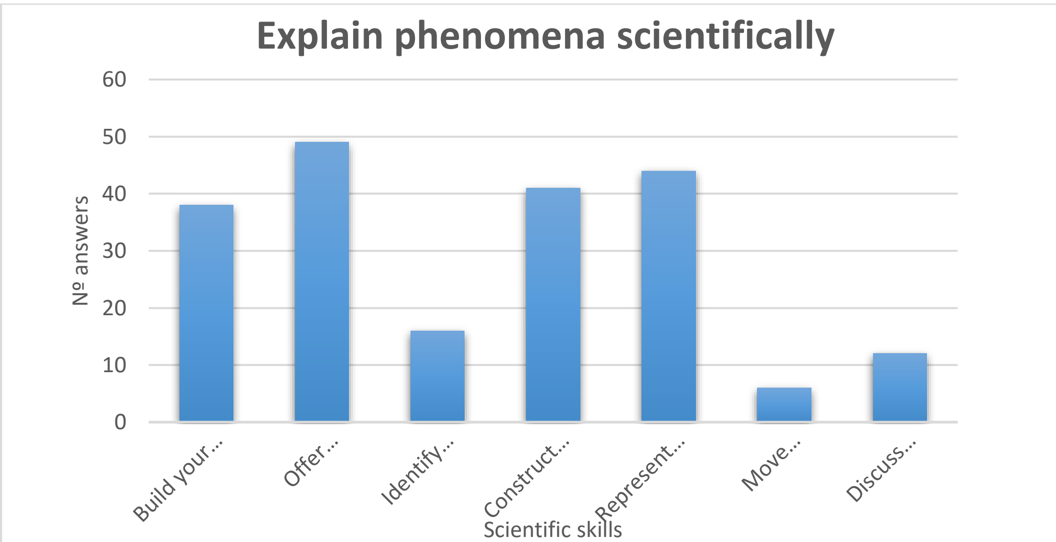

Figure 3.Frecuency of skills related to explain phenomena.

The third dimension (Figure 4) is the only one in which pre-primary and primary teachers select the option 'none of the above', arguing that these competences are difficult to address in their classrooms.

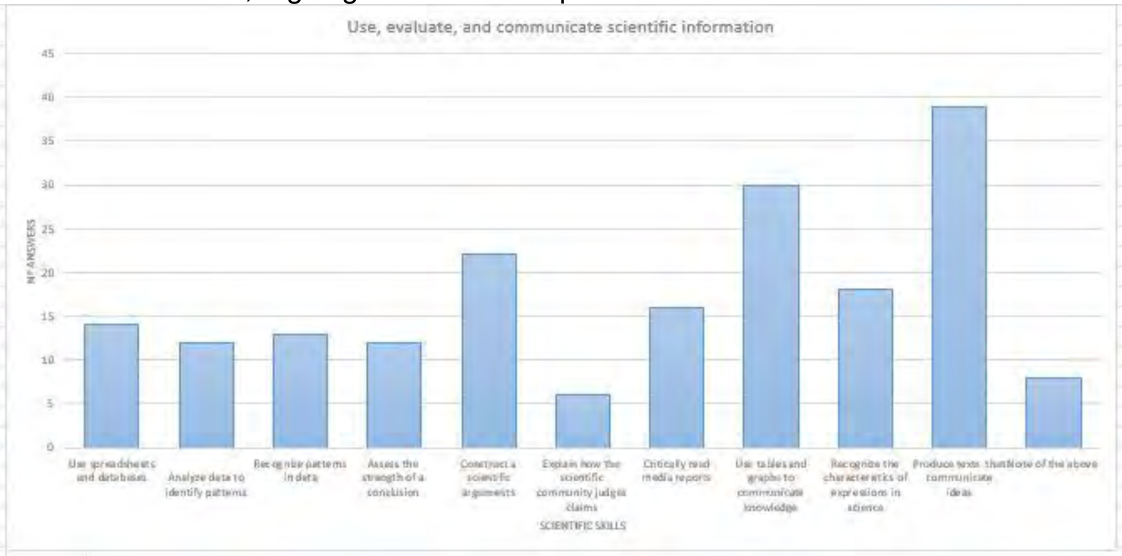

Figure 4. Frecuency of skills related to use, evaluate and communicate information.

Among the teachers who consider enhancing it, two skills stand out: using words, tables and graphs to communicate knowledge, and producing texts. Others, such as "explaining how the scientific community judges claims" hardly appear.

Conclusions

In this work, we characterise what in-service teachers consider as scientific skills. 33 out of 60 in-service teachers relate scientific skills with the development of skills such as the formulation of questions; however, there are still 25 teachers who believe that knowing science implies understanding how science is created and evaluated.

Regarding the scientific skills, investigations planning is the dimension they work on most. For some of them, use, evaluate and communicate knowledge is the most difficult to carry out due to students' age. As for what specific skills teachers point out in each dimension, those that involve producing knowledge predominate over those that require evaluating it. These results are consistent with the literature on how students develop scientific practices. Aspect to which special attention must be paid to change this pattern.

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Environmental education: Citizenship, literacy, climate change

Ask, find out, & act: A Lesson Study on environmental citizenship

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Theoretical background:
In light of the recent global climate crisis, Environmental Citizenship (EC) is an increasingly important learning aim for biology education. Biology teachers want to incorporate more affective learning aims in their teaching, yet they experience difficulties with teaching EC, especially with normative aspects (Authors 1).
A potential teaching approach that could support teachers when teaching EC (Authors 2) is Socio-Scientific Inquiry-Based Learning (SSIBL; Levinson, 2018). It employs three phases: Ask, Find out, and Act (**Table 1**). In an EC context, the Ask-phase has students ask authentic questions about an EC issue based on action-oriented knowledge (Jensen et al. 2002), and related to the five key sustainability competences (Wiek et al., 2011). During the Find out- phase, students use Socio-Scientific Reasoning (SSR, Sadler et al., 2007) and practice Wiek et al.'s (2011) System's thinking competence to map the issue. Finally, during the Act-phase, students take action based on their findings from the Find out-phase, which concerns Sass et al.'s (2020) action competence in SD, and Wiek et al.'s (2011) Strategic competence.

Table 1. SSIBL's phases of Ask, Find out, and Act, with associated EC theoretical context.

SSIBL phase	Theoretical context	
Ask	Action-oriented knowledge (Jensen, 2002)	Causes, Effects, Visions, Change strategies
	Key sustainability competences (Wiek et al., 2011)	Systems thinking competence, Anticipatory competence, Normative competence, Strategic competence, Interpersonal competence
Find out	Socio-Scientific Reasoning (Sadler et al., 2007)	Multiple perspectives, Critical thinking, Appreciating complexity, Ongoing inquiry
	Systems thinking competence (Wiek et al., 2011)	Relations, Loops, Scale, Cascading effects, Stakeholders
Act	Action competence (Sass et al., 2020)	Knowledge, Skills, Willingness, Outcome expectancy, Efficacy expectancy
	Strategic competence (Wiek et al., 2011)	Barriers, Carriers, Effectivity, Intentions, Alliances, Side effects, Norm changes

Key objectives:
Despite SSIBL's potential to foster EC based on these theoretical principles, it has not yet been extensively tested in a biology context. This study provides an empirical background for SSIBL's potential to foster EC in the context of biology education. The research question is:

> *What is the contribution of an extended SSIBL-based biology lesson series on lower secondary student EC development?*

Research design and methodology:
Study outline: Lesson Study (LS; Authors 3) was selected as the research method, since it is a cyclical process which allows for teachers and researchers to collaboratively design, implement, and test lessons in practice, focussing on student learning. A two-lesson series was developed and tested in two classes, completing one LS-cycle.
SSIBL's three phases formed the backbone of this double lesson on the school canteen. First, students

practiced Systems thinking by thinking of variables associated with the issue, exploring their relationships, and observing the nature of loops in their systems. Then, they explored potential places to improve the situation by means of their systems and a whole class activity which enables exploration of opinions and values. Finally, they redesigned a product for the school canteen and gave advice to school canteen personnel regarding their adapted product.

Participants: Two classes of students participated in this study (18 female, 2 undisclosed/other, 31 male; average age 13.7). Informed consent of parents or guardians was obtained beforehand. Lessons were taught by the class's own teacher (two male teachers, each with over 20 years of experience).

Data collection: Audio recordings were made of student group discussions during the lessons (6 groups in class 1, 5 groups in class 2, each of 4 to 5 students).

Data analysis: Group discussion recordings were annotated in NVivo (version 1.7) and relevant stretches were transcribed verbatim. For these analyses, closed coding was used, based on the models described in **Table 1**, with the addition of truthfulness and background knowledge in Jensen's (2002) model. After coding of the data, a second coder coded all the data, and interrater reliability was established at 100% agreement after discussion of the coding differences.

Findings:

The number of questions students asked are reported in **Table 2**. These most strongly relate to Wiek et al.'s (2011) competences of Systems thinking and Strategic competence, whereas no questions were asked related to Anticipatory competence. An example of a typical Strategic competence question is: "You say cucumbers need to be transported sustainably, how should they go and organise that?" (c1g3). On the other hand, all of Jensen's (2002) action-oriented knowledge categories were covered by student questions, with background knowledge, causes, and effects being most common.

Table 2. Number of questions asked by students, categorized by Jensen's (2002) action-oriented knowledge and the additional categories of truthfulness and background knowledge, and coupled to Wiek et al.'s (2011) key sustainability competences. Size of the circles corresponds with frequency.

	Causes	Effects	Visions	Strategies	Truthfulness	Background knowledge
Systems thinking competence	25	18			5	41
Anticipatory competence						
Normative competence	1	1	5			
Strategic competence	2	2	1	13		
Interpersonal competence	1	3			2	1

Concerning the Find out-phase, it becomes clear from the student discussion recordings that most aspects of SSR and of Systems thinking competence were discussed (**Table 3**). Relations were by far the most numerous aspect of Systems thinking competence, whereas signs of SSR mostly related to using perspectives and critical thinking. One student for instance shows critical thinking in their reaction to one of their peers: “No, we have just seen one video, that doesn’t mean that it is like that in all of Italy!” (c2g3). A typical conversation during this phase, displaying systems thinking characteristics, looked like this:

Student 1: “That is an S [*from Same, a relationship between variables*], right?”
Student 2: “An S, yes, and the number of greenhouses also affects the amount of CO_2 emissions, so that is an S too” (c1g3).

Table 3. Number of times students used aspects of Socio-Scientific Reasoning (Sadler et al., 2007) and aspects of Systems thinking competence (Wiek et al., 2011) during the lesson series.

	Socio-Scientific Reasoning aspects	Systems thinking competence aspects
Group discussions	42 Perspectives	145 Relations
	30 Critical thinking	35 Stakeholders
	20 Complexity	29 Loops
	17 Uncertainty	25 Cascading effects
		23 Scale

During the Act-phase, students clearly showed Knowledge and Skills aspects of action competence (**Table 4**). However, Willingness and Confidence were less common, and if they occurred, were frequently negative. Concerning Strategic competence elements, Intentions, Barriers, and Carriers of the student plans were observed most frequently in student discussions.

Table 4. Action Competence (Sass et al., 2020) and Strategic Competence (Wiek et al., 2011) aspects found in student discussions during the lesson series.

Action competence aspects		Strategic competence aspects
Knowledge	49 Problem knowledge	31 Intentions
	28 Action strategies	18 Barriers
	7 Norms and values	9 Carriers
		1 Alliance
Skills	16 Ability to think of alternatives	9 Barriers
	10 Critical thinking	7 Carriers
	2 Positive stance to alternatives	2 Feasibility
	1 Negative stance to alternatives	1 Intentions
		1 Norm change
Willingness	2 Low	
	0 Conditional	
	0 High	
Confidence: Outcome expectancy	6 Negative	
	1 Positive	
Confidence: Efficacy expectations	2 Negative	
	1 Positive	

Conclusions:

Results show that a diverse set of EC competences can be observed in student discussions on the sustainability issue of the school canteen. From this, it follows that SSIBL has the potential to allow students to practice these EC competences within the context of biology education. Next to these successes, some aspects of EC are less clearly developed, for instance related to Wiek et al.'s (2011) anticipatory competence or the negative aspects of action competence such as outcome and efficacy expectancy. Despite this, the results presented here are a promising sign for the applicability of SSIBL as an educational approach to provide room for implementation of more competence-driven educational goals related to EC for biology education.

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anonymised for peer review
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Environmental issues, causes and solutions in Greek secondary education biology textbooks

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Hopeful climate education in a time of climate crisis

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Rationale

Climate change can be considered one of the greatest crises of our time. Pre-service biology teachers (PSBT) in the applicants' teacher education institutes have repeatedly indicated that learning to teach about climate change is one of their greatest needs because of their desire to become teachers that make a hopeful contribution to a better world and climate. From PST final reports, however, it appears that time and again they fail to do so. This is also evident from literature, PSBT feel very committed to this topic, but at the same time concerned and anxious about the climate themselves and ignorant in how to provide hopeful and effective teaching about the climate crisis in their secondary school internship classes (Bean, 2016). Around climate change, people from all over the world feel different types of unrest (WHO, 2020). Among young people, this unrest appears to be highest. For example, 75% of young people (16-25 years old) find the future frightening and 56% that humanity is doomed to destruction (Hickman et al., 2021). Studies on the effects of climate change on young people reveal that pessimism, guilt, hopelessness and fear are common in the new generation (Ojala, 2012; 2022). These feelings in turn can lead to powerlessness, polarization between groups and apparent stagnation.

Education can be a key for improvement, yet research shows a strange paradox around the influence of education: the way teachers currently teach about climate change only allows feelings of fear, hopelessness and pessimism to increase rather than decrease (Ojala, 2022). What is needed is to have a new generation discover from hope that another future is possible and that even a crisis includes profound problems- though complex and intractable- for which solutions can be found. This different, hope-filled lens focuses not on obstacles, but on the ability to arrive at new strategies along the way to a different future. Hope currently receives attention from many different angles (e.g., Goodall, 2021). Although many authors endorse the need and importance of hope, to date there has been little innovation in the ways in which hope can have a practical effect and lead to change, let alone in education.

Key objectives:

In our research, we propose an biology education intervention to teach climate change from a lens of hope to shift young people's perspectives away from what seems to impede and toward the ability to strategize towards a different future. Our intervention, 'hopeful climate education', is aimed at making students from this new generation active and engaged problem solvers focusing on the new that they are bringing to the world - that they are creative and powerful (Arendt, 1958).

Methods:

We enacted 'hopeful climate education' in two teacher education institutes in both the Netherlands and Germany (n=32). A mixed methods research design was used in which data were collected in the form of PSBT desires and intentions to teach hopeful education about climate change, their related beliefs and a pre-post questionnaire 'hope concerning climate change' (Ojala, 2012). Analysis was done by clustering beliefs in order to make sense of intentions and statistical analysis of the pre-post test.

Findings:

In table 1, we show what participants would do if they A. had all the money, time and no fear, without a pre-described curriculum (miracle-question), and B. were to teach hopeful climate education for their own classes in the upcoming weeks (intentions). What becomes clear is that most participants come up with ideas and intentions for their classes that are in line with the design principles of hopeful education (such as showing good examples, having discussions and setting up projects), worked out in yet a very creative and action-oriented way, such as make seed bombs or creating a bee trail (see table 1 for examples from both Germany and the Netherlands).

Table 1. Survey of what PSBT would do in their classes considering hopeful education.

Nationality of the PSBT	Answers to the miracle-question*	Intentions for in your class
Germany	First do lessons in nature, visit to the reforestation projects. Next, let students conduct projects in small groups aimed at innovation for climate-friendly living on one's own environment	Start-up hopeful projects aimed at innovations in one's own environment
Germany	Go to places that are very affected: glaciers, lands, etc. Then walk to places where projects have the task of saving the earth .	Illustrate affected places in class using pictures and videos. Next, have students think of solutions. But it's difficult to do anything with gigatons.
Germany	I would create a bee trail, install a solar power system, and produce a musical with the students.	I can do this in my class, but if we had even a bit more time, we could achieve much more.
The Netherlands	Invite Jane Goodall to visit my class	I will have students explore for themselves what inspiring initiatives already exist I am going to invite or use video of an inspiring guest speaker who focuses on the positive
The Netherlands	In front of our school, there is a lawn (grass area). Let's turn this into a forest!	In class, we will raise awareness of the influence one student can have on ecosystems by showing good examples. Next, we will make seed bombs that students can spread on their way home.
The Netherlands	We will visit companies that have positive impact (water purification, wind farm, meat substitute company) and discuss the dreams that students have.	I will have students choose a sector they want to work in and see what solutions already exist in that sector, can you add one yourself? (drawdown project website)

* If you had all the money, time and no fear, without a pre-described curriculum, what would you do?

Participants also expressed their behavioural, normative and control beliefs about the extent to which hopeful education can be achieved in class. In terms of behavioural beliefs (advantages and disadvantages), participants mentioned prevalent advantages such as that 'hopeful education gets students involved', 'it gets them to see what actually can be done' and 'this fights pessimism'. Disadvantages were stated to be, e.g., 'if this would be enough for lasting change'. As control beliefs (helpful and hindering factors), participants primarily mentioned hindering factors such as time and that other curriculum topics have priority (little attention in the curriculum and textbooks). Lastly, participants also mentioned that they experienced support from their school supervisor and colleagues, yet were afraid for criticism from parents and school leaders who thought different (normative beliefs). Scores of the pre-post questionnaire ('hope concerning climate change' (Ojala, 2012)) show no significant change, which implies that hope around climate change did not reinforce anxiety and stress as was reported in earlier literature.

Conclusions:

Hopeful education leads to the formulation of specific intentions that are both directed toward hope for the climate as well as easy to implement in actual teaching. Many intentions show to be action-oriented and PSBT often used their creativity to find non-traditional ways of conveying climate hope. We also found hindrances for teaching hopefully, such as not enough time, curriculum coverage and a lacking attention in textbooks for climate change and climate hope. Also, the different opinions that others could have could make it a controversial issue to teach in school. Implications for national curricula and international recommendations will be discussed at the ERIDOB conference.

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Ready to teach climate change? Predicting biology pre-service teachers' beliefs and self-efficacy

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Theoretical background

Teaching the socio-scientific issue of climate change is a demanding task for biology teachers, not only because of its highly complex and interdisciplinary science content but also due to the spreading of doubt around the scientific consensus of the climate crisis or the political dimension of the topic (Plutzer et al., 2016). Also, its urgency and resulting climate anxiety among school students pose difficulties to teachers (Hickman et al., 2021). Unfortunately, these immense challenges seem not to be reflected by current teacher training programs, where (CCE) is rarely integrated (Grund & Brock, 2018). Improving current biology teacher training programs in CCE is therefore necessary to foster the professional development of the next generation of biology teachers in this field.

For this purpose, understanding pre-service teachers (PSTs) dispositions is pivotal, since those are considered to amplify or filter how PSTs develop their professional knowledge in a specific learning context (Carlson et al., 2019). In the framework of the Refined Consensus Model, this study therefore aims to investigate PSTs' personal beliefs about teaching climate change and their self-efficacy for doing so (Carlson et al., 2019).

Prior studies in this context have mostly been exploratory or solely focusing on beliefs about the existence or anthropogenic causes of climate change, which are supposed to play a minor role in today's European context (Lamb et al., 2020). Our study aims to investigate future biology teachers' beliefs about CCE in a more holistic way and, by testing their predictive ability on CCE self-efficacy, the connections between those beliefs. In light of prior research, investigating the role of PSTs' socio-demographic factors forming their CCE beliefs is in addition promising (Plutzer et al., 2016).

Objectives

We investigated:

1) How are PSTs' beliefs for conducting CCE in the future expressed?
2) What socio-demographic factors can form such beliefs?
3) How can CCE self-efficacy be explained based on the investigated teacher beliefs and socio-demographic factors?

Research design and methodology

An online questionnaire was administered at all universities which offer biology teacher training programs in Austria. A total of 397 PSTs trained for middle and high school biology (M_{Age}: 24.72; SD = 4.47; 72.8% f, 24.9% m, 2.3% d) took part in the study. To measure CCE beliefs, the Teacher Beliefs of Environmental Education Questionnaire (Mullens & Cater, 2019) was adapted for the context of CCE and PSTs. Following the original instrument, five discrete constructs, aligning with the Theory of planned Behavior (Ajzen, 1991), were defined: CCE behavioral (CCE Beliefs), normative (CCE Support), CCE control beliefs (CCE Motivators and CCE Concerns) as well as attitude (CCE Self-Efficacy) toward teaching CCE (Table 1). The sub-scales were adapted based on previous research, except for the self-efficacy scale which had already been adapted to the CCE context (Li et al., 2021). All sub-scales used a 5-Point Likert answer format. After adaptation, scales were tested in a pilot study (n = 108) for their test quality. Demographic items (age, gender, political ideology, study semester, CCE teaching experience) were included. The scale data were analyzed using descriptive and inferential statistics.

Findings

The study reveals that the investigated PSTs scored high on the CCE Beliefs scale, e.g., indicating that teachers should take time to integrate CCE concepts into their teaching (Table 1). At the same time, PSTs scored high on the CCE Motivators scale, e.g., they agreed that their concern about climate change influences their decision to teach CCE in the future. In contrast, PSTs scored low for believed CCE Support, e.g., they believed to not have enough resources for conducting CCE in the future. The mean values of the CCE Concern scale was on a medium level (Table 1).

Table 1
Main Instruments and Descriptive Statistics

Construct	Instrument/Scale	Item example	*M*	*SD*	α
CCE Support	Environmental Education Support [a] (Mullens & Cater, 2019)	I have adequate class time for teaching CCE (in the future).	2.82	.69	.93
CCE Concerns	Environmental Education Concerns [a] (Mullens & Cater, 2019)	I have concerns regarding the possibility of politically influencing students when teaching CCE (in the future).	3.01	.81	.75
CCE Motivators	Environmental Education Motivators [a] (Mullens & Cater, 2019)	My attitude towards climate change influences my decision to teach CCE (in the future).	4.18	.69	.81
CCE Beliefs	Environmental Education Beliefs [a] (Mullens & Cater, 2019)	I believe that climate change education encourages students to take action to resolve climate change issues.	4.35	.52	.91
CCE Self-Efficacy	Climate Change Education Teacher Efficacy Belief Instrument [b] (Li & Monroe, 2021)	I have the necessary skills to teach this topic (in the future).	3.55	.78	.92

Note. n = 397. The scales used a 5-Point Likert answer format. M = mean, SD = standard deviation, α = scale reliability measured by Cronbach's alpha; [a] Adapted to the context of CCE and PSTs; [b] Adapted to the context of PSTs.

Table 2
Multiple Regression Analysis

	β (SE)				
	CCE Support	CCE Concerns	CCE Motivators	CCE Beliefs	CCE Self-Efficacy
Age	.00	-.21***	-.02	-.01	.17**
Gender	.02	-.03	-.16**	-.04	.11*
Political ideology	.12	.2***	-.13*	-.26***	-.02
CCE Teaching experience	-.17**	.01	-.00	.12*	.37***
Semester	-.07	.01	.03	-.03	-.11*
CCE Support	—	-.01	-.01	.08	.23***
CCE Concerns	-.01	—	.16**	-.05	.00
CCE Motivators	-.01	.19**	—	.36***	.16**
CCE Beliefs	.10	-.06	.36***	—	-.03
CCE Self-efficacy	.29***	.01	.17**	-.03	—
F (*p*)	3.83 (< 0.001)	4.52 (< 0.001)	12.36 (< 0.001)	12.56 (< 0.001)	13.56 (< 0.001)
R^2 (adj. R^2)	.101 (.075)	.117 (.091)	.267 (.245)	.270 (.248)	.285 (264)

Notes. The coding of gender was 1 = female, 2 = male. Political ideology was measured with a 7-point Likert scale (1 = very left, 7 = very right). *p < .05. **p < .01. ***p < .001.

Following multiple regression analysis, political ideology predicted three out of four investigated teacher beliefs sets, while CCE teaching experience was found to predict two out of four investigated teacher beliefs sets (Table 2). Age and gender each predicted one set of teacher beliefs, while the study progress had no predictive ability.

When it comes to explaining PSTs' CCE Self-Efficacy, only two of the investigated CCE teacher beliefs sets, CCE Support and CCE Motivators, were significant predictors. Also, socio- demographic factors such as CCE teaching experience, age, gender and semester played a significant predicting role (Table 2).

Conclusions

Until now, studies have been lacking that systematically investigate PSTs' CCE beliefs, connections between those and predicting socio-demographic factors. By providing valuable insights into Biology PSTs' CCE dispositions, our study can inform teacher educators and contribute to improving current Biology teacher training. Hereby, our recommendations include increasingly integrating the political dimension of climate change, topic-specific teaching practice, and highlighting existing supportive infrastructure for CCE (e.g., teaching materials, peer groups, CCE initiatives). More results will be presented and discussed at the ERIDOB 2024.

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Students' conceptions and conceptual reconstruction 4

Students’ Moral Conceptions of Animal Ethics to Foster Decision-Making Competence

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Teacher noticing practices of preservice and in-service biology teachers regarding teaching and learning focusing on student conceptions in evolution classes

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Theoretical considerations

Teacher noticing is an important component of professionalism in teaching that can be developed in teacher education. Teacher noticing refers to the ability of teachers to notice and interpret significant events in the classroom (van Es and Sherin 2008). As teachers are confronted with a complex and dynamic nature of classroom events, they need to distinguish between aspects important and irrelevant for the instructional quality. In evolution education, diagnosing and addressing well-known student conceptions (e.g., teleological, and anthropomorphic conceptions) is important for the instructional quality (Harms and Reis 2019). In line with a socio-cultural perspective with reference to Goodwin (1994), we conceptualize teacher noticing as a social practice. Consequently, unconscious, self-evident routines of action as well as experiential and reflexively unavailable knowledge influence teacher no- ticing. This kind of knowledge, which can be referred to as tacit knowledge, enables routine action, since teachers intuitively know how to react. These perspectives on teacher noticing enable a contribu- tion to research by exploring the tacit knowledge about teaching and learning and the social dimen- sion, which are largely unexplored.

Key objectives and research question

For teacher educators, knowledge about teacher noticing practices is a relevant source for better understanding the pre-service teachers' status quo and for identifying aspects of teacher education. This presentation will thus address the research question: *How* do preservice and in-service biology teachers talk about teaching and learning regarding the way student conceptions are addressed in an evolution lesson, and what tacit knowledge guides their discourse?

Methodical approach

In total, 115 preservice and in-service biology teachers participated in 31 group discussions (3-4 people, average duration: 45 min.) and 9 individual interviews (average duration: 25 min.). A video clip was used as a stimulus for data collection, showing classroom interactions between students and with the teacher, particularly in relation to addressing teleological and anthropomorphic conceptions. The data were analysed using the documentary method and the tacit knowledge is methodically captured as frameworks of orientation (Bohnsack 2010). In a first step, the explicit (literal) meaning of *what* is said is reconstructed. In a second step, the implicit (tacit) meaning of *how* it is said is reconstructed, thus, revealing the underlying implicit understanding of teaching and learning processes. Of the 40 cases available, 15 were fully interpreted and used for generalisation in the form of typification with- out applying a priori categories to the data.

Results

In all 15 cases, the preservice and in-service biology teachers talk about the relationship between teaching and learning, and between student conceptions and scientific norms. These two common themes are consistently processed in a framework of orientation, which we reconstructed as evaluation mode. In all cases, participants evaluate both the teacher's actions and the students' learning process, and it is constructed and addressed as a problem that students have not sufficiently learned scientific norms. As the evaluation mode is the common feature of all 15 cases, it represents the base type. It consists of three components, which we call basic orientations (s. Tab. 1). This presentation will use significant transcript extracts to illustrate the base type and three reconstructed types, indicating differ- ent teacher noticing practices.

Tab. 1: Overview of the base type and the three types on the common theme of teaching and learning

Base type: mode of an evaluation – basic orientations	Type 1: teaching as direct transmission of scientific norms	Type 2: teaching as enabling learning by establish- ing and facilitating ac- cess to scientific norms	Type 3: teaching as contingent mediation between stu- dents' conceptions and scientific norms
A) Orientation regard- ing a conceptualization of teaching and learn- ing	Teaching as direct trans- mission of scientific norms Learning as an intake of scientific norms	Teaching as enabling learning by establishing and facilitating access to scientific norms Learning is understood as the use of learning opportunities pre- struc- tured by teaching	Teaching as contingent mediation between stu- dent conceptions and scientific norms Learning as linking stu- dent conceptions and scientific norms
B) Orientation regard- ing role attributions for the teacher and the students	Teacher as a dissemina- tor of scientific norms Students as recipients	Teacher as the designer of the learning environ- ment Students as users of the provided learning envi- ronment	Teacher as mediator be- tween student concep- tions and the scientific norms Students responsible for the relation of concep- tions and scientific norms
C) Orientation regard- ing attribution of causes for insufficient learning	Learning is insufficient because of the wrong way of representing sci- entific norms in teaching (transfer problem)	Learning is insufficient because scientific norms are not taught and learned in an appropriate way (problem of the learning environment and learning opportuni- ties)	Learning is insufficient because of the insuffi- cient mediation between student conceptions and scientific norms by teacher and students (problem of mediation inherent to teaching and learning)

Conclusions

We conclude that approaches to professionalisation should aim to get preservice and in-service teach- ers to explicate and reflect as much as possible upon teacher noticing practices, especially the action- guiding tacit knowledge about teaching and learning. The three reconstructed types can be used as starting points for reflection, and they can help teacher educators to develop learning opportunities by knowing better what to expect. The study of cases using lesson videos and a professional development programme called video clubs (van Es and Sherin 2008) seems promising, as these approaches offer possibilities for addressing many of the challenges in teacher education that our results point to.

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Interconnectedness in biology education

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Theoretical background or rationale

Biology operates at incredible spatial- and temporal-scales, ranging from the atomic-level through to the ecosystem-level and the microsecond timescales of cellular, to geological timescales of evolutionary processes. This complexity makes teaching biology a difficult endeavour and drives conceptual simplifications to more manageable levels (Scheiner, 2010; Nehm, 2019). Breaking down biology to apparently separable conceptual entities makes a more holistic understanding more difficult for the student. Francois Jacob, one of the most influential biologists of the 20th Century, wrote that "*Every object that biology studies is a system of systems."* (Jacob, 1974). More recently, there has been a reemergence of interest in and seminal contributions to the teaching of biology through the concept of "systems thinking" (Boersma et al., 2011; Assaraf et al., 2013; Tripto et al., 2016; Verhoeff et al., 2018). Systems thinking is well-grounded in both Biology and education theory, including concept inventory theory and scaffolding and constructivism theories. However, systems thinking is rather difficult for students to grasp. Our working hypothesis is that the concept of "interconnectedness" is central to systems thinking across all scales and "interconnectedness" could offer a teaching simplification for systems biology. To begin to test this, we asked to what extent school pupils are able independently to make connections between concepts in biology when exposed to a novel topic of current biology research.

Key objectives:

We sought to identify the science concepts *and their interconnections* that students draw upon when they are asked to discuss their approach to a current Biosciences research problem that is novel to the students and for which there is *no currently accepted single solution within the Biosciences research community*. Participants are, therefore, relieved of the *tyranny of trying to find the "correct" answer* and can explore their ideas more fully.

Research design and methodology:

We used a mixed-methods research paradigm where students in secondary schools of either year-10 or year-12 (roughly 15-years old or 17-years old, respectively) were asked to discuss in groups of six pupils *their approach to solve a current research problem* which was scaffolded by the presenter to add levels of complexity as the discussions progressed. The presenter was a Biosciences researcher, either at the doctoral level or a permanent staff member of a University Biosciences department. In our talk, we will introduce four different research discussion topics. Year-10 pupils have discussed Polyethylene biodegradation by Galleria mellonella (Bombelli et al., 2017) and year-12 pupils have discussed three topics; cell separation in the developing nervous system (Astick et al., 2014), light-activated proteins, and quorum sensing within biofilm production as a model for the origins of multicellularity. Importantly, discussants were told explicitly that there was *no correct answer currently known* and therefore that *their ideas were valid as long as they were arguably scientifically sound.*

Students were given a paper-based, randomized-order 7-item questionnaire both before and after the discussion session. The questionnaire used a set of validated items based on attitudes to science and scientists, comfort with science study and discussion of science and student concept integration. Discussions were recorded, pseudonymised and transcribed with themes, biology concepts and interconnections between concepts identified by reiterative thematic coding. Questionnaire responses from over 100 pupils from each of year group have been collected. Recordings of year-12 discussions have been analysed for over 30 participants each for cell separation and light-activated protein topics.

Findings:

Wilkoxon signed-rank tests show statistically significant medium to large effect sizes for six of the seven questionnaire items, including, importantly the item related to concept integration. Qualitative analysis indicates that concept integration across all scales of biological knowledge as well as socio-scientific and economic concepts were also introduced by the year-12 participants.

Conclusions:

School pupils can approach diverse current biology research problems drawing on a range of science concepts and making connections between those concepts. Current biology research, time and again, highlights just how interconnected Biology is at all scales and between scales. For example, recent studies of gene regulatory networks, community effects in developmental cell-migration, the interplay of cell behaviour with the physical properties of connective tissue and the gut-brain axis, indicate that interconnectedness is a fundamental feature of biology even just within one organism. Interconnectedness is also a crucial feature across organismal, population and ecosystem scales. Further, socio-scientific issues highlighted by the covid pandemic and climate change demonstrate just how interconnected Biology is with human, animal and planetary health and wellbeing. In the talk, we shall also discuss that social constructivist ideas, aided by artificial intelligence-driven graph theory concepts could help students make their own connections within and across scales of biological concepts during teaching events. The concept of interconnectedness, when well-scaffolded, could be a simplifying principle that would aid student understanding of systems thinking in Biology and further cement Biology education at the nexus between science and society.

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Narrative writing and multimodal texts

Influence of a board-game narrative framework on student's narrative writing in the context of evolution teaching

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Rationale
This research studies the narratives of lower secondary school students after playing a board-game about evolution integrated into educational resources for lower secondary school. The board-game 'Darwinium' was designed by a team of researchers and teachers and places middle school students in the fictional situation of researchers observing the evolution of fictional animal populations placed in an experimental dome. The game mechanics and the story it tells is considered a "narrative framework" (Author, 2021). In other words, it sets the initial situation, a set of theoretical and methodological standards on which the players/students can base the reconstruction of future events. During a game play, players have to report on the evolution of their fictional animal population in verbal narrative form and graphic form. This project is based on previous work that has highlighted the difficulties in apprehending the theory of evolution of living things and the ideas of chance that are linked to it (Author, 2018; Fiedler, Sbeglia, Nehm & Harms, 2019).
A previous study (ESERA, 2023) revealed that after playing the game Darwinium, some students express an understanding of certain important ideas related to evolution in accordance with scientific knowledge. The game seems to enable students to consider the question of randomness in the evolutionary process, even though for some this idea of randomness coexists with their finalist conception of evolution. There was also an absence of the idea of contingency in the explanations of evolution.

Key objectives
The purpose of this paper is to study how the narration unfolds in students (13-14 years old) writings after a play activity about the mechanisms of evolution. The hypothesis is that the "narrative framework" given by the elements of the game influence the narrative texts produced by the students and the way they consider what is possible in the game, and in particular how they consider the idea of contingency.

Narrative framework of the board-game Darwinium
The board-game Darwinium, designed for this project, engages students in a fictional scenario of experimental evolution where players study changes occurring in a fictional experimental population placed in an experimental dome in response to conditions imposed by the player but not totally controlled.

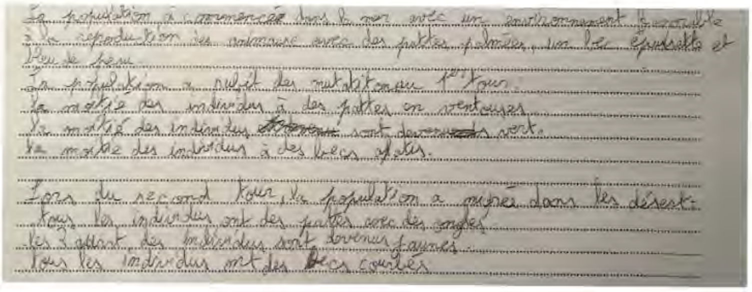
The salient elements that defines the "narrative framework" are:

- populational thinking: the narrative of the game and texts found in the element of the game never mention individuals but rather use groups of animals
- generational change: a timeline is not expressed as such, but the game introduces a temporality through the succession of generations in the population of animals
- material artefacts manipulation that introduce random processes:1) Tokens, representing various traits of the populations of the game, thrown in a dice tower (random distribution of alleles during reproduction) (see fig. 1.1). 2) Preparation of the number of tokens to throw in the dice tower (contingency of natural selection). 3) "Traits" cards drawn depending on the sorting result of the dice tower (random mutations) (see fig. 1.2). 4) "event" cards randomly drawn (see fig. 1.3).
- modification of the environment: players can move their population to a different environment and "event" card impact the conditions of the environment.

Figure 1.
Overview of parts of the Darwinium board-game. (1.1 token thrown in the dice tower (left) and selected (right), 1.2 “Trait” card drawn, 1.3 “Event” card drawn)

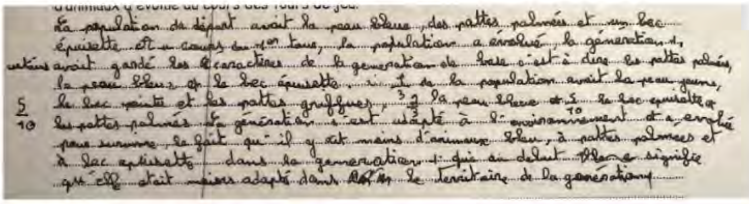
Methods

The proposed methodology is based on the analysis of the narrative writings produced by 57 students (13-14 years old) during a debriefing session after a game session of "Darwinium" conducted in a biology class. During a debriefing session, students are asked to write the story of their population, to express their understanding of what happened during the game and how it related to evolution. This study analyses a selection of narrative texts (N = 30) that feature either ideas of chance in evolutionary processes or obstacles related to chance in evolutionary processes (finalism), or both, with the aim of highlighting the ways in which these texts fit into the narrative framework set up by the game (see fig. 2). The narrative texts were then analysed on the basis of structural and functional narrative criteria.



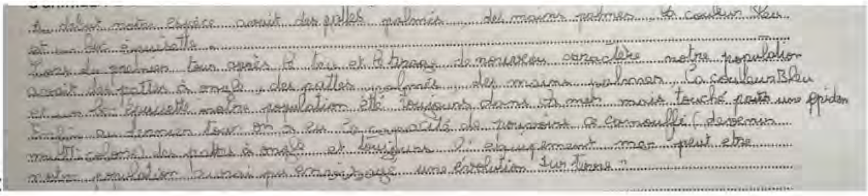
1 :

1: The population began in the sea, with an environment favourable to the reproduction of animals with webbed feet, a landing net beak and blue skin. The population underwent mutations in the first round: half of the individuals have legs with suction cups, half of the individuals have turned green and half of the individuals have flattened beaks.
In the second round, the population migrated to the desert: all the individuals have feet with nails; three quarters of the individuals have turned yellow; all the individuals have curved beaks.



2 :

2: The starting population had blue skin, webbed feet and a landing net beak. During the first round, the population evolved; in generation 1, some had kept the characters of the base generation, i.e. webbed feet, blue skin and a landing net beak. One third of the population had yellow skin, a pointed beak and clawed feet, two thirds blue skin and 5/10 the landing net beak and webbed feet. The generation adapted to the environment and evolved to survive, so the fact that there are fewer blue animals with webbed feet and landing net beaks in generation 1 than there were at the beginning means that they were less adapted in generation 1's territory.



3 :

3: At the beginning our species had webbed feet, webbed hands, blue colour and a landing net beak. In the first round, after sorting and drawing the new characters, our population had nail feet, webbed feet, webbed hands, blue colour and a landing net beak. Our population was still in the sea but affected by an epidemic. Finally, in the last round, we had the ability to camouflage ourselves (become multicoloured), nail legs and still the sea equipment; perhaps our population could have considered evolving on land.

Figure 2. Example of student's narrative writing with ideas of chance in evolutionary processes (2.1), finalism (2.2), both (2.3). Translation by authors.

Results

The texts produced show varying degrees of closeness to the "narrative framework": some do not detach themselves from the elements and temporality of the game ("*we were able to draw cards and the cards allowed us to draw characteristics to have a new population*"); others introduce elements of the temporality of the evolutionary processes ("*The population began in the sea, where the environment was favorable to the reproduction of animals with webbed feet, a beak like a landing net and blue skin (...). During the second round, the population migrated to the desert, where all the individuals have feet with nails"*). Finally, others use chance as an event that triggers a disruption in an oriented evolutionary process. ("*chance during reproduction, at the level of genetics, has given the appearance of new traits such as hooves and hook- like beaks which are not, however, adapted to the sea environment*").

Conclusion

The analyses show two ways of inserting the students' narrative texts into the narrative framework of the game:

- either by an explanation limited to the rules and progress of the game,
- or by explanations that use certain structural and functional elements to make the narrative framework more intelligible.

This work of narrative configuration (Ricœur, 1984) of the elements of the game enables some students to produce narratives telling a story of evolution of their population.

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Testing a double grid to analyze students' productions on the concept of natural selection. Study in France and Belgium

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Theoretical background

We place our research within both an epistemological framework related to the construction of the concept of natural selection (Canguilhem, 1989; Foucault, 1966; Gayon, 2012; Huneman, 2009, Mayr, 1959/1976) and a classical didactic framework that works both on conceptions (Driver & Erickson, 1983; Orange & Orange Ravachol, 2013; Posner et al., 1982) of students relating to this concept and on the way in which didactic research findings can demonstrate (de Hosson & Orange, 2019).

It is at the articulation between these epistemological referents and a didactic analysis (sequence conducted in a 3e class in France, 15-year-old pupils, Gobert & Lhoste, 2023) that we have constructed a double grid for analyzing pupils' explanations on the theme of natural selection.

The two grids, based on previous research, are as follows (Tables 1 and 2).

Table 1. Building blocks of a population approach (Gouders, 2023 after Gobert & Lhoste, 2023)

Sheet 1: The typological approach is linked to a population approach. Species characteristics are linked to the variability of individuals within a population. There is a progressive shift of focus from a "type" individual representative of a species, to "individuals" making up a species. Variability between individuals of the same species is thus considered, but in a still static approach. It's a population-typological approach.

Sheet 2: We take into account that certain events can lead to a change in the distribution of certain traits within a population over time, but we do not yet take into account historical time (i.e., the fact that current biodiversity is the result of contingent events and invariant processes); this is a population approach without taking historical time into account.

Sheet 3: There is a link between changes in the frequency distribution of certain traits within a population (via various events) and their consequences in terms of the transmission of genetic information over generations, which impacts the frequency distribution of certain alleles over time, potentially leading to a transformation of the population. This is a population-based approach that takes historical time into account.

Table 2. Development of the concept of selection (Gouders, 2023 after Gobert & Lhoste, 2023)

Sheet 1: Selection is seen as a phenomenon in which certain individuals are replaced by others on the basis of their phenotypes. It is based on predation or differential survival, which articulates phenotype and environmental conditions. Pupils are in a one-off horizontal narrative.

Sheet 2: Time (generational) and reproduction are taken into account, enabling the construction of an idea close to that of a rate of renewal or replacement, through the suppression of phenotypes that are not advantageous in the environment. The idea of differential reproduction provides an explanation of population evolution.

Sheet 3: The notions of gametes and alleles present in the population are linked to the phenotype in order to envisage differential reproduction and the variation of allele frequency distributions over time. There's the idea of increasing/decreasing an allelic frequency through differential reproduction, linked to a phenotypic advantage at the individual level.

Sheet 4: There's the idea of selection as discriminating sampling over generations, through differential reproduction linked to variable environmental conditions, to explain the dynamics of the population's gene/allelic pool. This is probabilistic population reasoning.

Key objectives

Both grids are the product of case study research. In this paper, we seek to investigate the robustness of these tools. In so doing, we contribute to a discussion of what can be proven in science didactics research, the validity of results being an "object in tension" (de Hosson and Orange, 2019, p. 9-11).

Research design and methodology

Data collection

Two sequences on the theme of natural selection were set up in France (16-year-olds, Depoix, 2023) and Belgium (18-year-olds, Gouders, 2023). The situation in France is based on a classic natural selection situation, that of the birch moth. The situation in Belgium is based on another classic speciation situation, that of the Galapagos finches.
In both cases, students were asked to produce an explanation as part of a diagnostic assessment. The results were collected. Scientific debates were organized. They were filmed and transcribed. Final summative assessments were carried out. They were collected. All these data constitute our corpus of data.

Methodology

All these productions were analyzed using the double analysis grid presented in a previous section, in order to measure the heuristic dimensions of the tool produced, which obliged us to define indicators to position a given production in a given category. This analysis was carried out and discussed by the three authors of the paper

Findings

The two analysis grids actually enable us to do several things.

1/ They have enabled us to assess the potential of the situations proposed to students, insofar as they involve the problem of natural selection to a greater or lesser extent. In this sense, our double grid could have a heuristic value in helping teachers construct the most optimal situations for confronting students with both the problem of natural selection and that of a population-based approach to species.

2/ The two grids enabled us to make a detailed analysis of the pupils' initial productions obtained during the diagnostic assessment. Our results show that, in both France and Belgium, very few students, prior to learning, are in Sheet 1 of natural selection and population thinking. Obstacles linked to a typological approach to species (Mayr, 1976) and to finalism seem to be strongly present, despite the fact that students are confronted with this notion of natural selection during their school career. From this point of view, the two- fold grid we have produced can be used to consider issues relating to the curricular management of the problem of natural selection, from lower to upper secondary school.

3/ The two grids reveal changes in the students' reasoning over the course of the two sequences, whether during the scientific debates that took place in the sequence in France or the one in Belgium. From this point of view, the two grids produced have great potential to help teachers manage scientific debates, by providing them with benchmarks for evaluating the proposals put forward by the students ni situation.

4/ The two grids enabled us to show changes in students' conceptions between the beginning and end of the sequence. Although our work is not based on the logic of conceptual change, but rather on problematization, our results show shifts in students' positions in relation to the two grids, which we can analyze in detail.

Conclusion

Our results establish the heuristic character of the two grids constructed during previous research. This heuristic dimension of the products of case study research for the analysis of other teaching and learning situations with students of a different age and in other contexts seems to us to be an indicator of the validity of what was initially produced. This is not evidence in the sense of evidence-based education, but rather evidence based on practice. It is the robustness of the tools that we believe we have uncovered in this paper.

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Playful writing for learning about cycles in nature

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Introduction

Wonder and joy stimulate creativity (Glăveanu, 2019), they are ubiquitous in play and build the basis for learning (Zosh et al., 2013). Including tasks that allows students to use imagination when working with models in science, can broaden their perceptions about abstract processes. This study investigates how 11-12-year-old students write about cycles in nature when imagining themselves to be trapped inside a "bottle garden". The bottle garden is a model used in biology, consisting of a glass container with soil, water and a plant. The container is sealed after placing all the elements inside, representing an isolated ecosystem with water cycle and carbon cycle, among others. Many students find cyclic processes challenging, and approaches that allow students to combine everyday experiences, interests, knowledge and fantasy can enhance their experience of meaning and commitment to the topic (Kress et al., 2001).

Theoretical background and rationale

Play brings about several learning benefits (Christie, 2022) and may constitute one of various multimodal approaches to science topics. Multiple representations potentially enhance students´ opportunity to create meaning based on the combination of several modes (Kress et al., 2001; Lemke, 2005). As play, joy and wonder are precursors for creativity which is a necessity for bridging various experiences and pieces of knowledge to create new comprehension, this dimension should play a major role in science classrooms. However, on a general basis, play is a rapidly diminishing staple for today´s children (Zosh et al., 2013).

Including playful approaches as part of inquiry-based science learning can enhance various students´ learning opportunities, achievements and engagement. Also, it potentially raises the students´ opportunities to develop skills in creative and critical thinking, meeting the aims of the 21st-century skills (Binkley, 2012).

Key Objectives

The overarching issue we discuss is: *How can creative student texts about a science model include play and imagination that facilitate academic meaning-making among primary school students?*
We focus on two research questions:

1. How do the students express wonder when they imagine themselves trapped inside a "bottle-garden"?
2. How do the students use comparisons as part of a playful approach in written texts?

Methodology

The students (N=43) in two school classes in Norway were challenged to imagine that they were shrinking and trapped inside a bottle-garden they had made as part of an inquiry-based teaching unit about ecology. To express their imagination they wrote a text about what they experienced inside the bottle. In one of the classes, the task was repeated four times with different scaffolding over eight months. The first time, the students chose what they wanted to write. The second time, they were asked to continue writing from two starter sentences. The third story included the same starter sentences, but the students were also asked to include specific concepts related to ecology. The fourth time, two or three students created a story together. In this study, the second text from four students from the same class are analysed (not previously published). The texts are analysed by a qualitative content analysis (Schreier, 2012) based upon a) reflections of Glăveanu (2019) connecting the relevance of wondering to learning in science, and b) the students' comparisons between events and objects, and language (Christie, 2022).

Findings

The findings reveal that the students express wonder and enthusiasm, by negotiating thoughts and understanding about parts of the process of photosynthesis, the carbon cycle and the water cycle. They connect the environment inside the bottle garden with sensory experiences ("the soil was wet and muddy").

To answer the second RQ, the texts illustrate that students use comparisons between objects in the bottle garden and experiences from everyday life. They also compare imagined feelings experienced in the bottle to real-life feelings like joy, fear, excitement, worry and happiness. Some of the students negotiate concepts and language, and compare science concepts difficult to understand, with everyday concepts perceived as meaningful.

Discussion and Conclusions

The discussion of the results emphasises how different students negotiate and express wonder about the science topic, and in what way this can involve a learning-potential. Also, the discussion revolves around how the students express various comparisons, and in what way this can involve a playful approach to the science topic. Based on prior research (Christie, 2022; Glăveanu, 2019; Glăveanu & Beghetto, 2017) differences among the student's expressions are discussed as ubiquitous for learning-processes building on play.

By creating alternatives and combining new and old information, the synergy effect can provide new knowledge, new questions and possibly provide fertile ground for the emergence of new learning opportunities (Glăveanu and Beghetto 2021; Glăveanu 2020; Cropley 1997). The potential of the texts in the context of assessment and recognition of students is highlighted.

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Teaching for plant awareness

Assessing the current didactic frameworks for plants: A need for a paradigm shift

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Theoretical Background

Despite the importance of plants for human welfare and sustainability, people seem to neglect and underestimate them. This is due to an already well documented phenomenon known as “plant blindness” (Amprazis & Papadopoulou, 2020). During the recent years some researchers shift from the original term “plant blindness” to other ones such as “plant awareness disparity” or “lack of plant awareness” (Pany et al., 2022). On these more modern attempts to describe this issue, four components are being identified as necessary to do so: a) Attention (limited attention to plants, limited visual perception), b) Relative interest (lower interest in plants than in animals), c) Attitude (low interest in talking, learning or spending time with plants) and d) Knowledge (lack of knowledge, alternative ideas & flawed mental models) (Pany et al., 2022). To counteract these negative aspects, in the literature there are several educational interventions including out of classroom learning, use of technology, interdisciplinary approaches and references to impressive plants’ aspects (Stagg & Dillon, 2022). Nevertheless, despite the plethora and the variety of all these suggested educational approaches, lack of plant awareness seems to be still recorded in recent studies (Barrutia et al., 2022), maintaining a considerable ambiguity regarding this issue.

Key Objectives

The present research calls into question the current didactic framework of “education about plants” and its potential to increase plant awareness, especially if it remains limited to educational interventions such as those proposed by researchers in the literature so far.

Considering the above, the main question of this research is the following:

1. What are the types and characteristics of the proposed educational interventions to raise plant awareness?

Research Design and Methodology

To answer these research questions, a systematic literature review was conducted to identify all studies including educational interventions for raising plant awareness. Since the term "plant blindness" first appeared in 2000, only studies published in peer-reviewed scientific journals from that year onward were examined. The keywords used in the search were "plant blindness", "plant awareness disparity", "lack of plant awareness", "education for plants", "plant sciences", "education for sustainable development", "botany", "botanical literacy" and "biodiversity education". The 25 studies that were finally selected out of 91, were analyzed and grouped according to the data they presented. Through the process of content analysis, the proposed educational interventions were examined and classified into main, mutually exclusive, predetermined categories of teaching approaches. To avoid overlapping categories, the criterion of the “place where the intervention takes place” was used, specifically whether an intervention took place outside or inside the classroom. To ensure the reliability of the analysis, a second analyst was involved to group all educational approaches independently, and to discuss the results later. This discussion continued until there were no disagreements at all. The overall methodology also included quantitative aspects, for an attempt was made to rank the educational interventions based on their percentage of occurrence in the studies examined.

Findings

Table 1 lists the main types of educational interventions proposed by the literature to raise plant awareness, along with the respective percentages of occurrence in the total number of the studies. Botanical gardens seem to stand out as a choice, while in general out of school activities are chosen by most of the researchers (Table 1). Besides these general categories, some additional characteristics were recorded the suggested educational interventions. More specifically, the vast majority of these interventions were of short duration; none of them involved a long-term modification of the school or the university routine. No data were collected in any educational intervention long after the entire research process (long-term follow-up test). Despite the link between plants and sustainable development, only one published study appears to integrate the entire proposed intervention in the context of education for sustainability or a modern sustainable school. Moreover, almost all suggested educational approaches focus mainly on plants as a cognitive subject instead of the student as a person with specific perspectives and values.

Table 1. Types and percentages of educational interventions to raise plant awareness in a total of 25 studies.

Types of educational activities for raising plant awareness	Percentage of occurrence in the total of 25 related studies
Educational activities specifically in botanical gardens	24%
Educational activities implemented within the framework of environmental education or in educational for sustainable development	8%
Highlighting impressive plant species/plant features within or outside of school	12%
Teaching about plants through cross-curricular approaches in other subjects within the school	8%
Other kind of educational activities implemented outside of school	36%
Other kind of educational activities implemented within the school	12%

Conclusions

Existing research on educational interventions to enhance awareness of plant organisms undoubtedly provides a valuable theoretical foundation for understanding and restricting the phenomenon of "plant blindness". However, the overall range of these educational options seems to be short-term and limited in scope, not aiming at a comprehensive change in the learner. Instead of assessing plant organisms as just another subject module that requires more teaching time, perhaps we could reconsider the existing didactic frameworks. The challenge is not to simply fill a knowledge gap, but to achieve a profound and substantial change in student's understanding, behaviour and perspectives, all as a result of critical thinking and reflection. To achieve the above, perhaps transformative learning can be an option (Kitchenham, 2008), especially since it is already considered to be effective for altering attitudes and mental models. Additionally, this learning framework has a prominent place in the acquisition of basic skills in education for sustainable development, as these are officially defined by the United Nations. By deploying transformative learning principles when designing teaching strategies for the vegetal world, a comprehensive approach emerges based on specific learning theories, deeper assessment methods, and alignment with the core of education for sustainable development.

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Prevent plant Blindness: an ethnobotanical approach to reflect with children their relationship with plants

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Plant awareness disparity in secondary school students' nature experiences

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Theoretical background

Plant awareness disparity entails overlooking plants, relegating plants to the background, viewing plants as undifferentiated utilitarian resource, and undervaluing the interdependency between humans and plants (Wanderseee & Schussler 1999). A recent systematic review found support for the different dimensions of plant awareness disparity, for example the ranking of plants as inferior to animals, and hypothesized that a decline in relevant experiences with plants is the reason for plants awareness disparity (Stagg & Dillon 2022).

Key objectives

This study investigates the role of plants and animals in secondary school students' self-reported, authentic nature experiences. The aim of this study is to characterize students' nature experiences with plants and animals quantitatively and qualitatively. More specifically, we tested the hypotheses that students find nature experiences with plants less memorable and less personally relevant than experiences with animals.

Research design and methodology

The participants were 814 school students (395 female, 371 male and 15 diverse, aged 10-18 years) from 20 secondary schools in North Rhine-Westfalia, Germany. Based on the draw-and-write method, the assignment was: "Draw an image and write a text about a moment in nature, which you remember particularly well." Furthermore, we asked students, among other things, to indicate how often such moments are and how personally relevant they perceive them to be. Furthermore, we used a short nature connectedness scale by Richardson and colleagues (2019). Relying on a previously tested coding rubric (Author in print), school students' nature experiences were analysed for inner and outer aspects of the nature experience.

Findings

Considerable numbers of nature experiences focused on either plants (n=129; 17% of 753 students who submitted text and drawing) or animals (n=155, 20%), but the majority of students portrayed nature experiences which involved neither plants nor animals (n=456, 60%). Plants featured primarily in recreational experiences (42.6% of the 129 nature experiences with plants) and less often in exploratory experiences (22.5%). In contrast, animals featured primarily in exploratory experiences (46.5% of the 155 experiences with animals) and less often in recreational experiences (20.6%). Like nature experiences with plants, experiences without plants and animals were primarily recreational (64.9% of the 456 experiences without plants and animals) and less often exploratory (18.6%). A Chi-Square Goodness of Fit Test was performed to determine whether the proportion of students reporting experiences with either plants or animals was equal between the exploratory and the recreational dimensions, which were the main dimensions found in this study. The proportions differed by type of experience (either animals or plants), $X^2(1, N = 188) = 22.51$, $p \leq .001$, with plants underrepresented in the exploratory dimension and overrepresented in the recreational dimension.

Secondary school students rated the perceived personal relevance of experiences involving plants (M 2.88; SD .84; Z= 4.08, p≤.001, r=.24) significantly lower than experiences involving animals (M 3.29; SD .75) and experiences involving neither plants nor animals (M 3.15; SD .75; Z=3.13; p=.002; r=.12). Furthermore, students reporting an experience with plants (M 2.77; SD .61) exhibited significantly lower nature connectedness than students reporting an experience with animals (M 2.98; SD .56; Z=2.77; p=.006; r=.16). There were no significant differences in nature connectedness between students reporting experiences with plants and students reporting experiences involving neither plants nor animals (M 2.85; SD .55; Z=1.09; p=.27).

A Chi-Square Goodness of Fit Test was performed to determine whether the proportion of students reporting experiences either with animals, or with plants or without animals and plants was equal between males and females. The proportions differed by gender, $X^2(2, N = 704) = 9.93$, $p = .007$, with the main difference being that 16.2% males and 25.8% females reported experiences with animals. Furthermore, we investigated whether the proportion of students who reported experiences with either pets (including horses) or wildlife was equal between males and females. The same analyses were done for students who reported experience with either plants as a utilitarian resource or plants as an object of observation. For experience involving animals, the proportions differed by gender, $X^2(2, N = 145) = 28.8$, $p = .001$, with 9.1% males and 53.83% females reporting experiences with pets, 90.9% male and 46.7% female students reporting experiences with wildlife. For experiences involving plants, the proportions did not differ by gender.

Conclusions

This proposal presents quantitative data because of limited space, but qualitative data will be illustrated with examples from the survey in the presentation. Sample size was sufficiently large and criteria of analysis sufficiently complex for this study to contribute to understanding plant awareness disparity in secondary school students' nature experiences. Although experiences with plants were only slightly less memorable than experiences with animals – judged by the similar numbers of both types of nature experiences – experiences with plants were less personally relevant than experiences with animals and experiences without plants and animals. Furthermore, students reporting experiences with plants exhibited lower nature connectedness than students reporting experiences with animals. Furthermore, plants featured primarily in recreational nature experiences, and not, like animals, primarily in exploratory nature experiences so that the role of plants is more peripheral to the nature experience than the role of animals. Plant awareness disparity, thus, shows itself in attitudinal and behavioral aspects: experiences with plants are less personally relevant than experiences with animals and plants are less frequently an object of exploration than animals. For biology education, providing personally relevant opportunities for exploratory nature experiences with plants is necessary to counteract plant awareness disparity.

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First steps towards a revision of the plant awareness construct: A Delphi study.

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Theoretical background or rationale

Over the last two decades, there has been a growing interest in the study of plant awareness (formerly plant blindness). An increasing number of studies have been conducted by researchers within and outside of biology education, e.g conservation biology (Balding & Williams, 2016) or cognition (Zani & Low, 2022). These studies often address different aspects of plant awareness, but the current definition lacks a multidimensional understanding and structure. The missing construct likely arises from the original definition of plant blindness since it only provides a list of one-dimensional descriptions of human perceptions and behaviors that are used to diagnose plant blindness (Wandersee & Schussler, 2001). This makes it difficult to navigate and understand the underlying construct and demonstrates the need for revision before it becomes even more blurred (Pany et al., 2022; Stagg & Dillon, 2022).

Key objectives:

Our current research attempts to revise the original definition of plant awareness and redesign the construct itself.

Following the steps suggested by Lambert & Newman (2023), we first clarified the attributes of the construct by analyzing the existing literature, followed by defining its entity. A Delphi study is currently being conducted to verify the dimensions and subdomains yielded by our literature review. This proposal discusses the results of its first round, additional rounds are going to be completed in November and February.

Research design and methodology:

We are currently conducting a modified Delphi study (Nasa et al., 2021) to validate the proposed plant awareness construct and to establish consensus on the definitions of the construct's dimensions. Based on a literature review, we defined each dimension (*attention, attitudes, knowledge, categorization*) and created Likert scale items to test them. Furthermore, to ensure our definitions fit the construct, we collected qualitative data through open-ended questions.

Our expert panel consisted of 13 psychologists, botany educators, and plant awareness researchers. Each researcher was selected because of their significant impact on the field. To achieve consensus in this study, an interquartile range of <1 (Hsu & Sandford, 2007) was set as the threshold. Once an item reaches consensus, it is removed from subsequent rounds.

Results are shared with the experts after each round, along with their individual responses. The qualitative data is used to rephrase the items before their subsequent rounds of use (Nasa et al., 2021).

Findings:

The first round indicates a reasonable agreement to revise the construct and supports three of the four proposed dimensions. However, qualitative data revealed the necessity for a more precise conceptualization of the dimensions. Besides, experts reached a consensus on the need to distinguish between attitudes and interest in plants, which is not currently present.

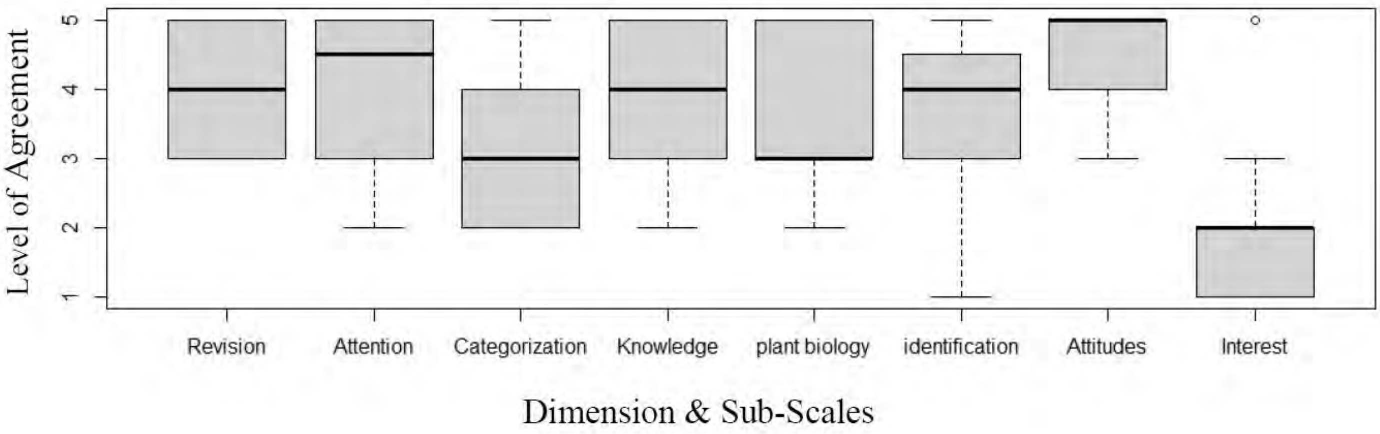

Figure 1: Expert consensus

The qualitative data highlighted the greatest disagreement regarding the knowledge dimensions, e.g., for some experts, it was not understandable why plant identification should be part of the construct (expert 6, pos. 12) while other experts rated it important. There is a significant distinction between the evaluations of researchers and practitioners regarding the ratings for the need to revise the construct.

Conclusions:
After the first round of the study, it is evident that our attempt to revise the construct of plant awareness resonates with the experts. These first results of our Delphi study already provide a clearer understanding of how plant awareness can be conceptualized.

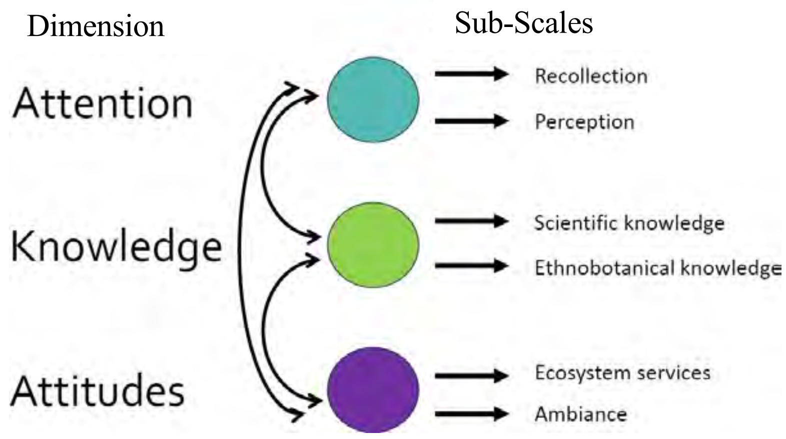

Figure 2: Plant awareness construct

Qualitative data provided insight into the necessary plant knowledge required for understanding pressing issues in the Capitalozene, including biodiversity, climate crises, and the SDGs. The focus shifted towards scientific (botany and ecology) and ethnobotanical knowledge.
As plant blindness symptoms do not allow for testing the construct itself, we used the collected data to develop an initial (working) definition of the construct:

Plant awareness is a multidimensional construct that reflects the level of someone's perception, understanding and valuation of plants.

Using the qualitative data to rephrase the items, the following Delphi rounds are scheduled for November 2023 and February 2024. The results and the validated, revised construct will be discussed at the ERIDOB 2024. The accomplished construct will be utilized to create a psychometric scale for statistical assessment after the Delphi study concludes. First insights of this scale will also be available to for discussion at ERIDOB. A unified framework provides a proven and rigorous approach to assess plant awareness, enabling the examination of diverse approaches to fostering plant awareness for the first time.

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Teaching for understanding and meaning making

Meaning-making in biology through analysis of word-categories

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Theoretical background or rationale
Several scholars (e.g. McComas et al, 2018; Seah et al., 2014) have emphasized that language usage in school science contexts may be characterized by high lexical density, abstraction, and technicality. In addition, the language in science classrooms has, according to Lemke (1990) specific characteristics related to the use of words, grammar, and semantic patterns; characteristics that may be a particularly challenging issue. Following Nation (2013) with focusing the word-level and biology, words can be grouped into three categories: (a) biology-exclusive words; concepts (e.g. *allopatric*, *genotype, stroma)*, (b) words found both in biology and elsewhere, but with different meanings; homonyms (e.g. *adapt, cycle, energy)*, and (c) general academic words (e.g. *converted*, *proceeds, originates*). All types of words are important in meaning making of biology to appropriate the semantic pattern of how biology is communicated in classrooms. In other words, teachers must understand how language influences learning and develop strategies to enhance students' successful appropriation of scientific language in the continuum between every-day and scientific registers (cf. Schleppegrell, 2016). Furthermore, might a specific focus on words be beneficial in the students´ meaning making processes (Logan & Kieffer, 2021).

Starting with the above-mentioned triadic idea from Nation (2013) have Authors (2019) developed a more fine-grained categorization with two main parts with three/four subcategories each. These are a) *content neutral words* divided in 1) *common words* (e.g. talk); 2) *unusual words* (e.g. disappointment) and 3) *general academic words* (e.g. consider) and b) *content related words* divided in 4) *homonyms* with 4a) *colloquial but content related words* (e.g. crossing) and *4b) academic and content specific words* (e.g. trait); 5) *content-typical* words (e.g. pollution) and 6) *content-specific* words (e.g. photosynthesis). Historically science education and classroom practice have focused the latter category - the concepts.

Key objectives
The aim of this presentation is to investigate language related issues, specifically words, in relation to meaning making of school biology in multilingual settings. This is done through a multidisciplinary (science education and linguistics) and quantitative approach in Swedish secondary schools. The research question is: what kind of words are challenging for students with Swedish language background and students with other language backgrounds.

Research design and methodology:
Starting out as a multi-disciplinary collaboration, between science educators and linguistics, meaning making of words was estimated through four different web-based vocabulary tests given to 232 students in grade 7-9. Two of the tests concerned biology (*genetics* respectively *prerequisites for life*) and was answered by 115 students. Each test had 15 words selected from the textbook that the students would study two weeks later. One sentence was chosen in which one word was made bold and the students were given four alternative suggestions as synonyms. The words belonged to five of the six categories mentioned above (common words was excluded) and academic/official dictionaries was used to categorize the words. Example of words in the textbooks that we chose were: 2) *unusual words* (e.g. contemplate); 3) *general academic words* (e.g. process); 4) *homonyms* (e.g. solution and crossing); 5) *content-typical* words (e.g. indicator) and 6) *content-specific* words (e.g. symbiosis). In addition, the students were asked about their first language and how long time they studied in Swedish school. This data made it possible to calculate potential significant differences between groups of students and categories of words.

Findings:
On a general level, significant differences were found between the performance (scoring 1-15 on the tests) of students with Swedish as mother tongue and those with other mother tongues and within the group that arrived in Sweden later than school start (see Figure 1 and 2).

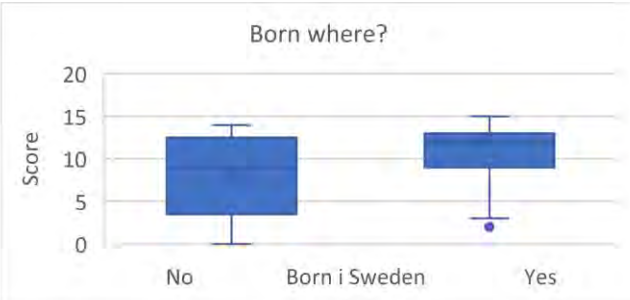

Figure 1.

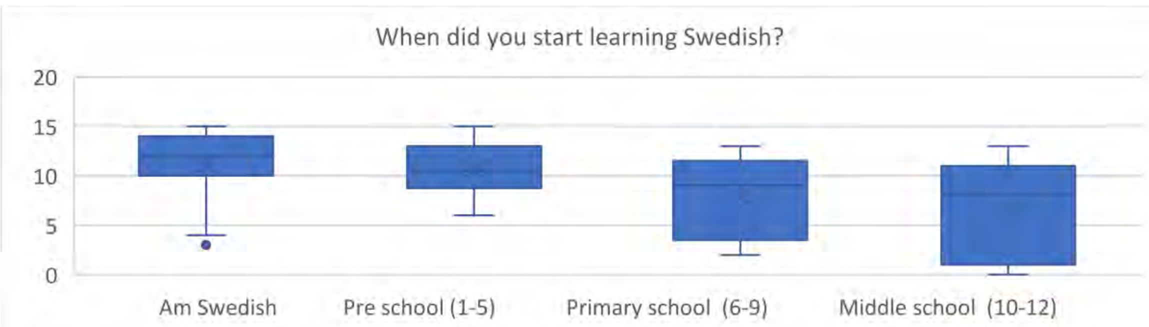

Figure 2.

We found significant differences towards two categories of words between students with Swedish as mother tongue and those with other mother tongues: 3) *general academic words* (e.g. cause and consist of) and 4a) *colloquial but content related words* (e.g. pass and branch). However, difficult word categories for all students were also two categories: *academic and content-related words* (e.g. trait and process) and *content-specific words* (e.g. symbiosis)

Conclusions:
It is not surprising that students with another mother tongue that Swedish scored less on a general vocabulary test and that the result correlate to time that the student has learned Swedish. Furthermore, it is not surprising that the content-typical words (the concepts) are difficult for all students. It has been shown before (c.f. Logan & Kieffer, 2021) but it indicates that the tests have some reliability.

The main contribution of this study is that it points towards types of words that are extra hard for the students to make meaning of. We argue that, with respect to students with another mother tongue than the language of instruction, it is especially important to give attention to the words that belong to the category *general academic words*. These general academic words are important in the biology classroom since they are the “glue” or connectors between the concepts. In other words, a scientific explanation is incomprehensible without the connectors that bind concepts (Silseth, 2018). It is hard to make sense of the important concepts without words like *consist of* or *becomes*. Therefore, teaching in biology should emphasize these general academic words along with the concepts.

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Probing Biology Teachers' Disciplinary Literacy Through Their Adaptation of a Research Article

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Theoretical background

Reading scientific texts has become accepted as a major required practice to become literate in science (NRC, 2012). However, most students do not progress much beyond basic reading skills (Goldman et al., 2016). Moreover, most texts that students read in science classrooms are from textbooks, popular media research, or internet review articles. These texts often do not reflect the core attributes of scientific reasoning and are antithetical to the epistemology of authentic science (Authors, 2019; Chinn and Malhotra, 2002).
Disciplinary literacy emphasizes the way of thinking in a discipline, including what is essential to pay attention to, what counts as evidence for an argumentation, what level of confidence the field has in the knowledge it produces, how texts are organized, constructed, etc. (Shanahan and Shanahan, 2008). These practices are inherently epistemic, based on ideas about what knowledge is valued (Authors 2018).

There are many challenges in integrating disciplinary literacy skills into science classrooms. For example, many teachers lack the knowledge about the vital role that literacy plays in enhancing science learning, and they fail to mentor their students in the necessary literary practices that would help them read in science (Osborne, 2014). Teachers need a sophisticated understanding of the nature of scientific texts and how they are used authentically by the scientific community. Therefore, effective professional development is needed to help teachers learn and refine the pedagogies required to teach these skills (Darling-Hammond et al., 2017).
Adapted Primary Literature (APL) refers to an educational genre specifically designed to enable the use of scientific research articles in high school (Authors, 2008). Primary Scientific Literature (PSL) articles are adapted to match students' knowledge, reading abilities, and cognitive skills, while retaining the authentic characteristics of the PSL article (Authors, 2015), and the scientific language (Authors 2019). Since APL articles represent the structure, linguistic norms, epistemic standards and content (arguments, claims, and evidence) found in PSL articles (Authors, 2015, 2019), these articles can be used to promote important aspects of scientific literacy that are harder to achieve using other text genres such as textbooks or popular articles.
Understanding teachers' justifications for their decisions in the adaptation process of scientific articles is essential because it illuminates what teachers notice, value, and see as important for students to learn. Teachers' justifications may, therefore, provide insights into teachers' understanding of disciplinary literacy and may shed some light on the challenges they face when asked to implement disciplinary literacy practices in their instruction. Therefore, in this study **we asked**: What kinds of justifications do in-service high-school biology teachers make when adapting a scientific research article for their students?

Research design and methodology

Participants

Twenty-one in-service high school biology teachers (with 5-20 years of teaching experience) adapted a PSL article. All the teachers taught at public schools from various locations in Israel and had a B.Sc. degree in biology. The writing sessions were collaborative in groups of 2-3 teachers (9 groups in total). The teachers were encouraged to reflect on their justification for changes they made to the article (omissions, additions), but also on justifications for leaving certain elements of the article unchanged.

Data analysis

Justifications of features of the PSL text that teachers chose to change or retain in the adaptation process in their written artifacts at the end of the course, were collected (n=265). Using a grounded analysis approach, we classified the justifications according to their type into four main categories. Two additional researchers validated a subset of the data (~20%). The initial agreement on the categorization was ~82%, and after a discussion reached ~93%. Further elaboration on the categories appears in the Results section.

Results

The teachers' justifications (n=265) included considerations along four dimensions: pedagogical, epistemological, content-based, and structural. We provide definitions and proportions of the categories and examples of teachers' actual justifications in Table 1. Here we focus on Pedagogical and Epistemological justifications.

Interestingly, we found that most Pedagogical justifications supported a *change* in the article, e.g. adding, omitting, or changing how the information was presented in the original article. However,
most of the Epistemological justifications were in support of *retaining* the way information was presented in the original article. This reveals a potential tension between Pedagogical and Epistemological justifications; in a sense, one may come at the expense of the other. For example, some teachers were less attentive to important epistemological features; they chose to omit rebuttals that appeared in the original article, and to leave only conclusions and evidence that support the claims. Some teachers saw the importance of transparency of methods or results but were less concerned with accurate and nuanced reporting of the methods or results.

Table 1: Categories of teachers' justifications when adapting an article for students

Categories of justifications (n=265)		**Examples (justifications appear in italics) & proportions out of all justifications**	
Pedagogical	Justifications focus on students learning needs and abilities. This includes justifications for adapting the text to match cognitive and reading abilities, and prior knowledge, creating learning opportunities, and promoting students' interest and motivation.	We omitted any information about polyphenol concentrations because *we want to reduce the cognitive load.* We added a question about the graph *so that students could practice graph analysis.*	64.1%
Epistemological	Justifications focus on using the article as a model for learning about the scientific epistemology and reasoning. This includes justifications for including reliable processes, transparency of information presented in the text and different aspects of the nature of science.	We kept the information that the effect of the pomegranate juice may be secondary [to the antioxidant properties of pomegranate juice]. *It is important that students will be exposed to the uncertainty presented in the article, and that they get to know articles in which not everything is proven and certain.*	24.2%
Content-based	Justifications focus on the content of the article to create coherence and continuity within the text.	We omitted any information about rampiril [ACE inhibitor] *because it doesn't connect directly to the experiment presented in the [APL] article.*	8.3%
Structural	Justifications focus on the texts' structure, for technical reasons.	We separated the results from the discussion, *because this is the acceptable structure of a scientific article.*	3.4%

Conclusions

We found two main types of justifications. Pedagogical justifications, regarding adapting the text to match student abilities and needs, and Epistemologic justifications regarding opportunities to learn and reflect on different epistemological practices and considerations of science.

Insights from this study highlight the tensions in balancing pedagogical and epistemological justifications when creating APL articles for students, avoiding extremes that could result in an unsuitable or overly simplified text. It also emphasizes the need for teachers to develop heuristics for effectively balancing these considerations.

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Nature experiences, Nature connectedness, systems thinking

Students' individual systems thinking during a scientific modelling process of a dynamic ecological system

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Theoretical Background

Mankind is facing a variety of serious threats. Biodiversity crisis and global warming, to name just two of many, represent complex phenomena that need to be addressed by humanity. Two approaches making complex phenomena accessible are systems thinking (e.g. Ben Zvi Assaraf & Orion, 2005) and scientific modelling (e.g. Schwarz & White, 2005). Systems thinking represents students thinking processes involved in analysing complex phenomena from a systemic perspective. Although various authors use different models to conceptualise systems thinking, many models define particular skills, for example, identifying the system organisation, analysing the system behaviour, and modelling the system evolution (e.g. Ben Zvi Assaraf & Orion, 2005; Mambrey et al., 2020). Scientific modelling, for comparison, is a tool for investigating and explaining complex phenomena (Schwarz & White, 2005). It represents a cyclic process of model development, evaluation, and revision (e.g. Krell et al., 2019).

Key Objective

Despite the differences, both concepts describe learners' engagement with complex phenomena. The aim of this study was to examine the relationship between both approaches on the individual level and in the comparison of learners' proceeding.

Methodology

In order to expose students to a complex ecological phenomenon, we developed a web-based simulation of an ecosystem based on the *R* package *shiny* (Chang et al., 2022). The simulation encompasses simple predator-prey relationships among six populations: red clover, pasture grass, European rabbit, graylag goose, red kite, as well as Canadian goose, which enters the ecosystem as an invasive alien species with a temporal delay. Students were asked to translate the presented phenomenon into a graphical model while thinking aloud. They had access to information regarding the population dynamics through the simulation. The time on task was determined by the students themselves, averaging M = 43.3 (SD = 17.7) minutes. A total of nine upper secondary level students (M_{age} = 16.7 years) were surveyed.

For data analysis, the think-aloud protocols were analysed using a qualitative content analysis methodology (Mayring, 2010). The coding scheme encompasses both, the skills of systems thinking and the activities of scientific modelling, which were independently coded by two raters each. The categories for systems thinking were based on an extended version of the classification of Mambrey et al. (2020). Scientific modelling was coded using a category system from Krell et al. (2019) that was slightly extended.

Findings

A total of I = 1412 segments about scientific modelling (I_M = 998) and systems thinking (I_{ST} = 414) were identified. Among the sample, it was possible to identify all three dimensions of systems thinking and the main phases of scientific modelling (see Table 1). However, there were large differences between students. Comparing their proceeding, it was possible to delineate three groups. Sole representative of the first group is *Emilia* (see Table 1). *Emilia* did not show any systems thinking. Her scientific modelling did not exceed the mental modelling despite an extensive exploration of the system. The second group includes students *Paul*, *Sophie*, *Tom* and *Charlotte*, who developed a model beyond mental modelling and demonstrate systems thinking. However, participants in this group neither did generate predictions based on their models nor did they model the system evolution. The third group – *Anna*, *Laura*, *Chiara*, and *Ben* – accounts for students that demonstrated all dimensions of systems thinking and all main phases of scientific modelling.

Table 1

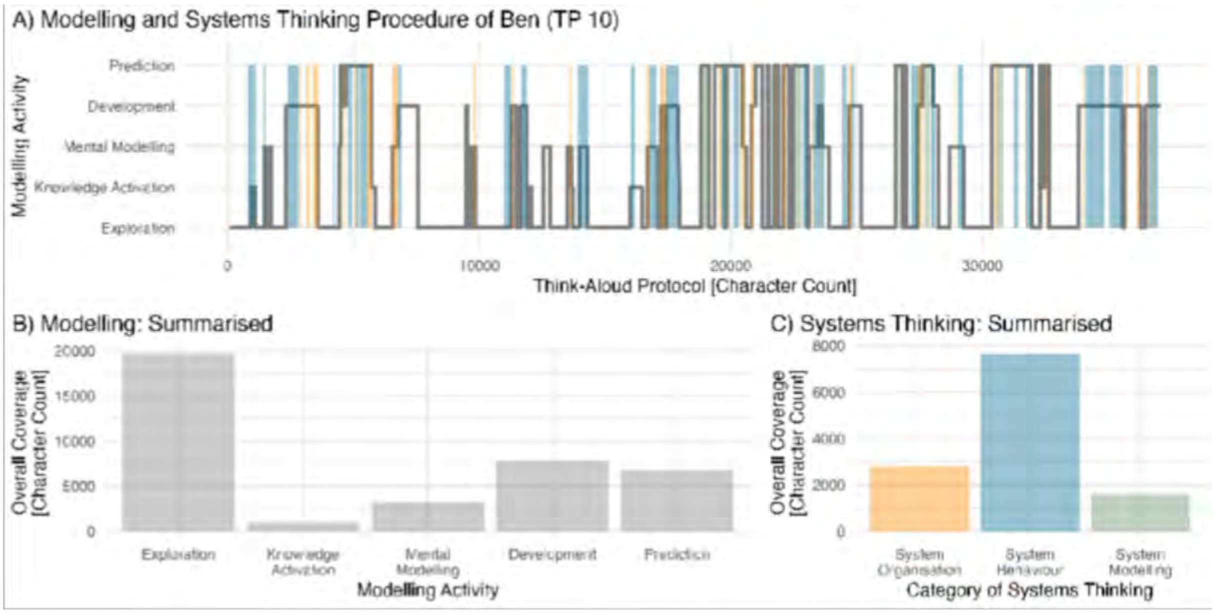
Scientific modelling and systems thinking activities of all participants. The categories of systems thinking are based on the classification of Mambrey et al. (2020). The categories of scientific modelling are developed based on Krell et al. (2019).

Student	Systems Thinking				Scientific Modelling					
	Identifying the System Organisation	Analysing the System Behaviour	Modelling the System Evolution	Σ	Exploration	Knowledge Activation	Mental Modelling	Development	Prediction	Σ
Emilia	-	-	-	-	83	5	6	-	-	94
Paul	31	16	-	47	33	4	9	14	-	60
Sophie	31	16	-	47	35	6	8	14	-	63
Tom	19	19	-	38	33	6	12	17	-	68
Charlotte	31	22	-	53	102	6	16	28	-	142
Anna	33	9	1	43	74	18	15	7	3	117
Laura	50	8	3	61	92	9	19	31	4	155
Chiara	23	19	3	45	56	4	5	23	10	98
Ben	43	29	8	80	116	6	13	20	36	191

Something that was quite similar between participants is their erratic proceeding in system modelling. All participants (except for *Emilia*/group 1) frequently switched between activities of phenomenon exploration and model development (see Figure 1). In terms of systems thinking, two-thirds of all students spent most time engaging in the analysis of the system's behaviour (see Figure 1), even though identifying the system organisation was coded more frequently (see Table 1).

Figure 1

Longitudinal and summative characterisation of Ben's proceeding in systems thinking and scientific modelling.



Conclusions

The results imply that the simulated phenomenon was sufficiently complex to induce scientific modelling (Krell et al., 2019) and systems thinking (Mambrey et al., 2020). Both approaches are noticeable related, but there are still considerable differences. The most obvious one being system exploration to be uncovered by systems thinking. Consistent with previous results , it was possible to cluster the participants by their modelling procedure (Göhner & Krell, 2022) and, with remarkable correspondence and not yet demonstrated, by their systems thinking. Except for *Emilia*, all students frequently switched between modelling phases of exploration and development (see Figure 1). However, this behaviour cannot be attributed to students' detecting a lack of fit in their models. Instead, their models develop gradually.

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How to promote students' interest in insects?

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Theoretical background:
Biodiversity is declining rapidly worldwide. The decline in insect populations and diversity poses a major challenge especially in respect of their vital ecosystem services (Sánchez-Bayo & Wyckhuys, 2019). To encounter the biodiversity crisis, knowledge about and appreciation of nature is highly important. Interest is regarded an important learning prerequisite (Krapp et al., 1993) and interest in nature is a central motivational precondition for the appreciation of and the readiness to protect biodiversity (Kals et al., 1999). According to the "Person-Object Theory of Interest" (POI) (Krapp, 1999) interest is defined as a specific relationship between a person and an object and is characterised by cognitive, emotional, and value-related components (Krapp, 1999).
As out-of-school settings hold great potential for the development of interest (e.g., Uitto et al., 2006), this project focuses on engagement with insects in out-of-school environments.

Key objectives:
The main research questions of this project are: Which factors play a role in promoting students' interest in insects and how should out-of-school learning activities be designed to inspire and maintain their interest?

Research design and methodology:
The project is based on the Design-based Research approach (DBR Collective, 2003). To measure interest and interest development we used a mixed-method-approach (Kuckartz, 2014). During preliminary investigations, we explored students' general interest in insects with a self-developed questionnaire (closed items with a five-point Likert scale, range 1 to 5 and open questions) and through half-standardised interviews (Kuckartz, 2014). To identify interest-promoting features of learning environments, we conducted half-standardised interviews with experts and evaluated existing programmes.
We analysed the quantitative data using SPSS (IBM Corporation, 2020) and the qualitative data conducting a qualitative content analysis (Mayring, 2010). Based on the results of our preliminary investigations, we derived design hypotheses for the development of own educational programmes.
During the formative evaluation, we tested and refined these design-hypotheses during three design-cycles (one three-day and two five-day outdoor summer-camps with students aged 12 to 16). Therefore, we developed a mobile field-station that can be transported with a bike-trailer and used in nearly every terrain. The programmes included a daytrip to a local natural history museum and fieldtrips to different local biotopes. Participant observations and half- standardised interviews were used for the evaluation.

Findings:
The questionnaire (N = 716, 10-18 years, M = 13,22) showed that interest in insects is generally low (M = 2.41, SD = 0,85), with significant differences between different groups of insects ($\chi 2(7) = 1921$; $p < 0.001$): Bees were perceived as quite interesting (M = 3.78, SD = 1.35), while true bugs were perceived as not interesting at all (M = 1.57, SD = 0.96) ($p < 0.001$). According to the qualitative data from the questionnaire and interviews with students (N = 5), the degree of students' interest in insects can be explained by their positive or negative perception of these animals. The students' perception is influenced by different characteristics of insects, personal experiences and the students' knowledge about insects. The interviews with experts (N = 5) and the evaluation of existing programmes (N = 5) showed that i.a. the morphology and diversity of insects, everyday contexts and the handling of living insects have an interest-promoting effect.

The analysis of the data of our formative evaluation (participant observation and half- standardised interviews (*N* = 27)) shows seven factors necessary for the development of interest in insects:

- satisfaction of basic physical needs
- satisfaction of basic psychological needs, especially the experience of competence (cf. Ryan & Deci, 2017)
- the experience of nature and direct experiences with insects
- the experience of novelty
- the perception of insects as personally significant
- the experience of epistemic curiosity
- the perceived acquisition of knowledge
-

The analysis showed that the out-of-school setting and the use of the mobile field station was beneficial for the students' interest development: self-directed exploratory investigation of a variety of different habitats laid the foundation for the experience of nature and direct experiences with insects. The interaction with living insects in the field allowed for constant moments of novelty which resulted in curiosity. Due to the inquiry-based approach and the support of mentors, the students were able to identify a great variety of insect species and felt like competent naturalists. The diversity of insect groups observed, and eye-catching or rare species were particularly beneficial for catching the students' interest. Finding out about their diet, life cycle, behaviour etc. played an important role in maintaining this interest. The students did not only state that they learned a lot but developed also new perspectives on insects and changed their values towards them.

Conclusions:
We show which interest-promoting factors play a role in the engagement with insects and how these can be promoted through the design of learning environments. Our research also shows that focusing on interest development can effectively stimulate important educational processes.

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Green time vs. Screen time: predicting nature connectedness in urban middle school students

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Theoretical background or rationale

Students are the future decision-makers and leaders and will be both the drivers and recipients of the consequences of environmental actions (Skilbeck, 2020; Wallis & Loy, 2021). Therefore, fostering pro-environmental behavior to achieve a more sustainable society is one of the key objectives of Education for Sustainable Development (ESD). Previous studies indicated that a connection to nature correlates positively with pro-environmental behavior (Kollmuss & Agyeman, 2002; Roczen et al., 2013). Studies show that time spent in nature is crucial for developing a connectedness with nature (Braun & Dierkes, 2017; Schultz & Tabanico, 2007). On the other hand, studies report that students nowadays are spending increasingly less time outside and more time in front of screens (i.e. mobile phone or PCs) (Larson et al., 2019). Studies reported a negative relationship between students' self-reported screen time and connectedness with nature (Michaelson et al., 2020; Price et al., 2022). Nevertheless, there are no studies that explore longitudinal changes in connectedness with nature and their predictors, such as green time and screen time. Thus, the present study aims to examine the longitudinal directional effects between students' connectedness with nature, self-reported green time, and students' self-reported screen time. We used longitudinal data and a cross-lagged panel structural equation modeling. The results of the longitudinal study are essential for planning specifically tailored teaching concepts for biology lessons and environmental programs.

Key objectives

Based on the literature reviewed, we specifically tested three hypotheses: 1.) Self-reported green time predicts students' connectedness with nature (H1). 2.) Self-reported screen time predicts students' connectedness with nature (H2). 3.) Connectedness with nature at the first assessment point (T1) predicts later subsequent levels of connectedness with nature at T2 and T3 (H3).

Research design and methodology

The study was part of a broader longitudinal project investigating environmental attitudes among Austrian urban middle school students grades 6-8. Three waves of data were collected at nine monthly intervals in grades 6 to 7. Participants filled out the same questionnaire at T1, T2, and T3 (T1 = February 2021, T2 = June 2021, T3 = October 2021). In June and October, intervention with direct nature experiences was conducted. The original sample consisted of 215 participants. We removed 52 individuals who missed one-time point. The final sample consisted of 163 participants (46.6 % female). The average age at T1 was M_{age}: 12.04, SD: .81, and at T3, M_{age}: 12.78, SD: .81. Students completed an anonymous paper-and-pencil questionnaire, which included the environmental attitudes scale "Inclusion of Nature in Self" (INS; (Schultz, 2002), two questions about green time, and screen time from Larson et al. (2019). Students were also asked to provide some general socio-demographic information. All analyses were made with R-Studio (version 1.3.1073) using the lavaan package, version 0.6-15 (Rosseel, 2012). Longitudinal associations between connectedness with nature and green/screentime were tested through a cross-lagged panel model (CLPM), which is a form of structural equation modeling (SEM) (Finkel, 1995).

Findings

Figure 1 shows the model with the hypothesized cross-lagged associations. We found strong predictive effects with previous test times for all three constructs. The path model provided a good fit to the data (χ^2 (36) = 215.731, $p < .001$; NNFI = .96; CFI = .92; RMSEA = .01). All significant cross-lagged relationships are included in the figure. The cross-lagged panel analyses supported the expected positive cross-lagged effects of green time (T1) on connectedness with nature at T2 ($\beta = .20$, $p < .05$) and T3 ($\beta = .16$, $p < .05$) from H1. In addition, green time ($\beta = -.03$, $p > .05$) at T2 predicted later green time at T3 and later screen time ($\beta = .06$, $p > .05$). Contrary to our hypotheses, screen time did not predict subsequent levels of connectedness with nature (H2). Finally, connectedness with nature at the first assessment point did predict connectedness with nature at T2 but not at T3 (H3).

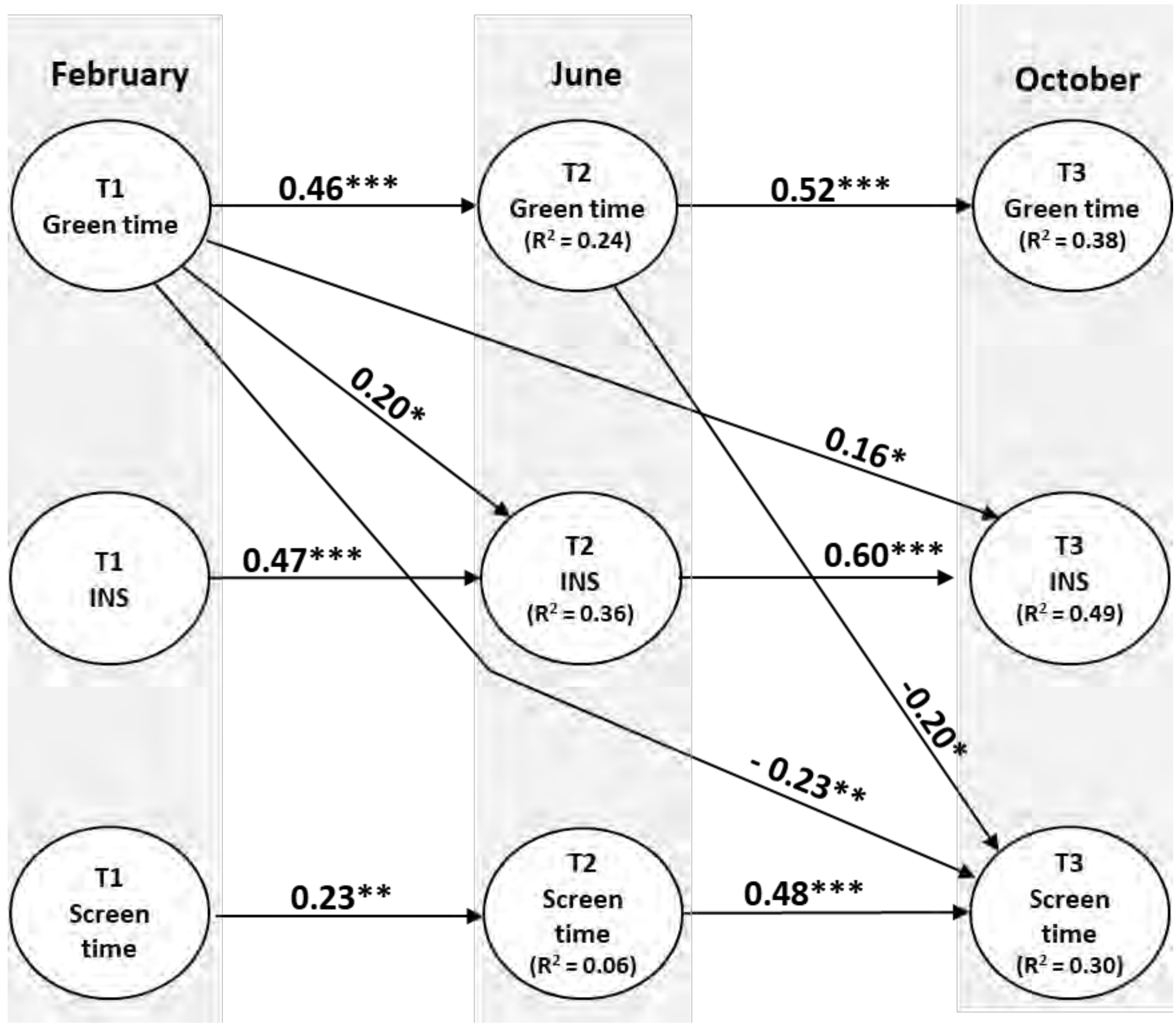

Figure 1: Connectedness, INS, green time, screen time; Only significant predictors are shown.
**** = p < 0.001, ** = p < 0.01, * = p < 0.05.*

Conclusions
Our results highlight the need for targeted actions to promote green time and raise awareness about the detrimental effect of green time on adolescents' connectedness with nature. It also suggests to conduct more studies about the influence of screen time on students' connectedness with nature. The main strength of this study is that it opens a new perspective on the longitudinal effects of students' connectedness to nature, self-reported green time, and screen time.

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Environmental education / Student argumentation

Between Rationality and Self-protection: Student-Constructed Arguments on Fast Food Consumption and Antibiotics Overuse as Public Health Issues in Biology Education

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Theoretical background

Health and nutrition are crucial parts of human life. They are also public and socio–scientific issues. They are presented in core curricula all over the world. What we consume and how we do it influences our bodies and well-being. The U.S. government's Healthy People 2030 in 2020 has redefined Health literacy as "the degree to which individuals have the ability to find, understand, and use information and services to inform health-related decisions and actions for themselves and others." FAO (Nutrition Education, 2021) recommends the use of active methods of learning about nutrition. We have chosen two topics related to nutrition: fast food consumption and antibiotic usage – with a specific example of using antibiotics in animal feed. As a learning tool, we have chosen argumentation as a form of interactive dialog, that helps in the construction of scientific knowledge (Kitcher, 1988; Jiménez-Aleixandre & Erduran 2007). Argumentation allows students to use the information and make evidence-based decisions while constructing an argument (Puig et al., 2012).

Research questions:

1) What issues high school students raise when they are challenged to respond to a structured argumentation in the task of whether fast food should be available in a school canteen?
2) What issues high school students raise when they are challenged to respond to a structured argumentation in the task of whether we should be adding antibiotics to animal feed?

Methodology

Data collection

The study involved 178 students from Polish schools aged 12-16. All the participants took part in classes focused on argumentation. Firstly, their personal knowledge about what an argument is was activated. Then, fundamental concepts related to the structure of arguments were presented. An example of an argument concerning smoking in public places was presented. Subsequently, students collectively attempted to create an argument regarding the impact of owning a dog on the owner's mood. Further on, they were asked to create their own argument regarding whether it is worth going on a class trip by ship in the Baltic Sea during the summer vacation. After independently constructing their arguments, students presented them on a forum and provided each other with feedback regarding the structure of the arguments, the logical coherence of their statements, and so on. The next part of the class was devoted to presenting information related to fast food consumption or antibiotics. The final part of the class was about students individually creating an argument in response to the problem question: "Should fast food be sold in schools?" or "Should we keep adding antibiotics to animal feed?". The class concluded with a discussion where students exchanged the arguments they had prepared. Their answers were collected and analyzed.

Data analysis

The presented study is a qualitative exploratory study. To discern qualities in students' reasoning revealed in their arguments, we used the framework of qualitative content analysis (QCA; Graneheim & Lundman, 2004; Graneheim et al., 2017). We performed a QCA in four steps, including: 1) discerning meaning units; 2) condensing codes; 3) creating categories; 4) formulating themes across students' discussions.

Findings
Four steps of the qualitative analysis framework were applied (Graneheim & Lundman, 2004) and are shown in Table 1 and Table 2.
Table 1 An example of QCA coding on the topic of fast food consumption.

1. Meaning units	2. Codes	3. Categories	4. Themes
A ban on selling fast food in schools would limit my freedom and the freedom to choose whether I want to be healthy	Restriction of freedom	Anti-health behaviors and attitudes as risk behavior	Restricting freedom of choice is a threat to autonomy
Fast food should not be sold at school because it negatively affects our health and brain function	Negatively affects our body/ unhealthy	The general influence of the food we eat and values	The general attitude toward own health

Table 2. An example of QCA coding on the topic of antibiotics usage.

1. Meaning units	2. Codes	3. Categories	4. Themes
This causes antibiotic resistance. As a result, there are more and more dangerous bacteria	Antibiotic resistance and the risk of dangerous bacteria	Danger from bacteria to humans	Biological (evolutionary) consequences of antibiotic overuse
Reducing the amount of antibiotics in feed has a positive impact on consumer health - fewer chemicals in food.	Chemicals in food	Healthy food	People's health as priority

Conclusions
When constructing arguments, young people approach issues that are close to them, directly affecting them, and requiring their own decisions (such as purchasing fast food in the school cafeteria) differently from those that are more distant and beyond their control (such as the matter of adding antibiotics to animal feed). In the first case, teenagers are more likely to reduce cognitive dissonance, defending own self-esteem as fast food consumers, by denying the harmfulness of fast food and emphasizing their advantages or appealing to the right to choose. Many of their arguments represent a bigger picture of their attitudes, values, or reasoning not strictly based on science. In the second case, students constructed arguments based primarily on science, even if there are some inaccuracies. In cases that do not depend on students' direct activity (adding antibiotics to feed), the threat to self-esteem does not hinder the construction of arguments; therefore, they are more rational and refer to scientific knowledge. This result may have educational implications for teachers while implementing argumentation in the classroom.

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COVID-19 protective behavior among French high school students

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College students' argumentation styles explored: a focus on the socio-scientific matter of genetic testing

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Theoretical background:
Educating students about social issues and their underlying scientific and technological principles is essential to achieving scientific literacy. Sadler (2004) clarified the relationship between scientific literacy and SSIs, stating that being scientifically literate requires making informed decisions about SSIs. Since SSIs are controversial, argumentation is one of the most suitable teaching techniques for their discussion. Argumentation is considered an important skill because daily life presents situations that require the evaluation of alternative solutions.
Various methods have been employed to assess the quality of arguments. Topcu et al. (2010) and others focused on the articulation of claims, justifications, counter-positions and rebuttals. Claims represent participants' stated positions in response to a given scenario, while justifications denote how participants support their claims with coherent evidence, principles or explanations. The grounds for a claim may be either elaborated, involving scientific data and social, economic or moral implications, or simple if devoid of such elements (Sadler & Flower, 2006). Counter-positions are opposing claims to the original articulated claim, and rebuttals are responses challenging counter-positions while reinforcing the initial claim. Individuals showcasing the ability to generate counter-positions and even refute opposing claims demonstrate a capacity to examine issues from diverse perspectives, indicate of higher- quality arguments (Topcu et al., 2010).

Key objectives:
The main goal of this study was to evaluate the quality of arguments in the socio-scientific field of genetic testing, formulated by college students who studied genetics as part of their B.Sc in "Medical Laboratory Sciences" at Hadassah Academic College, Israel.

Research design and methodology:
Twenty one students participated in a semi-structured interview which contained ethical dilemmas regarding genetic testing. For each dilemma, the students were first asked to express their opinion (Stage 1), and then asked to provide a counter-position (Stage 2) and a rebuttal (Stage 3).

An example:
Deafness may be caused by mutations, and it's possible to test embryos for mutations causing deafness.

a. If an embryo is tested and found to carry mutations that cause deafness, do you think that the pregnancy should be terminated? Explain! (**Stage 1**, intuitive answer).
b. Your friend disagrees with you. What will he say to convince you that he is right? (**Stage 2**, request for a counter-position).
c. What will you answer your friend? Explain! (**Stage 3**, request for a rebuttal(.

We created an argument-quality rubric, based on the rubrics of Topcu et al. (2010) and Sadler & Flower (2006). The quality of arguments was evaluated in two terms:
1. The extent to which justifications were grounded (Simple vs. elaborated grounds, Sadler & Flower, 2006). Grounds were considered elaborated if they were data or evidence based.
2. The presence of a counter-position and a rebuttal.

The rubric included the following argument levels:

1. Claim(s) + justification with simple grounds
2. Claim(s) + justification with simple grounds + counter-position
3. Claim(s) + justification with elaborated grounds
4. Claim(s) + justification with elaborated grounds + counter-position
5. Claim(s) + justification with elaborated grounds + counter-position + rebuttal

Findings:
In most cases, students provided justification with elaborated grounds (Table 1). Simple grounds, although less frequent than elaborated grounds at all stages, were more abandoned at stage 1 and became less abandoned at stages 2 and 3.

Our results show that counter-positions were expressed spontaneously, before an explicit request (stage 1), only in 21.29% of the arguments. However, when students were asked for a counter-position, the percentage of the arguments including it increased dramatically. After students were asked to provide a rebuttal (stage 3), the percentage of the arguments with counter-position was even higher (table 1).

We found that even when students provided spontaneous counter-positions (stage 1), they almost never formulated a rebuttal at this stage. At stage 2, after the request for a counter- position, 22.63% of the arguments contained a spontaneous rebuttal. Even after an explicit request for a rebuttal (stage 3), students phrased it only in 50% of the cases (table 1).

Table 1: The percentage of arguments with elaborated grounds, counter-position and rebuttal at each stage

	Stage 1 (n=155)	Stage 2 (n=137)	Stage 3 (n=60)	Chi-square	p-value
Justifications with elaborated grounds (%)	76.77	85.4	91.67	129.592	0.0196
Arguments with counter-position (%)	21.29	76.64	91.67	76.496	<0.0001
Arguments with rebuttal (%)	0.65	22.63	50	7.864	<0.0001

Examples of some of the argument types formulated by students are shown in Figure 1.

Figure 1: Examples of different argument types

A

Example 1 – Claim + justification with elaborated grounds + counter-position:

Interviewer: If an embryo is tested and found to carry mutations that cause deafness, do you think that the pregnancy should be terminated?

Student : No. Deafness is discomfort and nothing more. You can live with it very well. There are hearing aids, dogs, means that can help a person live with it. It's not a severe disease like Huntington's disease... It also depends on the population... I think that people today are more accepting toward people with disabilities... I'm secular, I don't know how it is for religious orthodox or ultraorthodox, but if a community accepts it and the family normalizes the situation and the child accepts himself the way he is, there is no reason not to bring a child like this into the world. [claims + justifications with elaborated grounds].

Interviewer: Your friend disagrees with you. What will he say to convince you that he is right?

Student : You can't ignore deafness, it is a disability. Some parents don't want their child to have any discomfort. It will bring difficulties and they will have to raise the child differently, learn patience and tolerance, learn sign language... There are many things that need to be done after the child is born so that he has a comfortable life, and if a couple wanted to avoid it, I would understand If they chose to terminate the pregnancy... [counter-position]

Interviewer: What will you answer them?

Student: I would try to understand what they reasons are. If I understood that their reasons are firm and relevant, I would let them (continue the pregnancy). If I still had doubts, maybe I would have tried to convince them not to abort the fetus. Eventually, it's their choice and there's nothing I can do about it.

B

Example 2 – Claim + justification with elaborated grounds + counter-position + rebuttal:

Interviewer: If an embryo is tested and found to carry mutations that cause deafness, do you think that the pregnancy should be terminated?

Student : No. In our modern world there are solutions for deafness. There are cochlear implants so there is a solution, it's not the end of the world if the child is deaf. That's why I wouldn't say "terminate". Only in cases of incurable diseases, when both the child and the family will suffer, I would say "terminate" [claim + justification with elaborated grounds].

Interviewer: Your friend disagrees with you. What will she say to convince you that he is right?

Student: (She will say) That the child will be isolated from his surroundings and form society [counter-position]. I will tell her she will have to work very hard so that her child can speak, hear well, understand what people are saying. It's a lot of social work, speech therapy, things like that. But if she works really hard, the child can somehow manage [rebuttal].

Conclusions:

In general, the students interviewed in this study formulated socio-scientific arguments with well-grounded justifications that contained both scientific data (for example, the mention of cochlear implants) and social implications, like society attitude towards disabled people. Elaborated grounds were more common when students were explicitly asked to provide a counter-position and rebuttal. A possible explanation is that when students were required to examine the issue from a different angle, they were forced to re-estimate it and eventually provided more detailed grounds. In contrast to the well-grounded justifications, the students' ability to spontaneously create counter-positions and to refute them was found to be low. However, students most often formulated a counter-position when explicitly asked for it. This was not the case for rebuttals, as in half of the cases students were unable to formulate a rebuttal even when explicitly asked to do so. We conclude that formulating counter-positions and rebuttals is not intuitive. Since science is highly imbedded in our daily life and decisions, our findings highlight the need to provide students with higher argumentations skills by including socio-scientific argumentation training in the curriculum.

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Teaching biology topics

Improving students' mental models of plant nutrition: insights from a design-based research

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Theoretical background:

The teaching-learning difficulties of the Scientific Model of Plant Nutrition (SMPN) are extensively documented in the literature. In fact, although plant nutrition is a central topic of Biology education, most students hold change-resistant alternative conceptions derived from intuitive or hybrid mental models (BLINDED, 2023). These have been a longstanding concern for both science educators and didactic researchers because constructing plant nutrition models close to the scientific consensus is basic to grasp ecosystem functioning or even understand multiple of the current socioecological issues (Hartley et al., 2011). Consequently, considerable academic efforts have been directed towards the design, implementation and empirical evaluation of Teaching-Learning Sequences (TLS) on the topic in the last years.

These attempts have served to identify key strategies, intuitive ideas or actionable elements that could be leveraged during instruction to improve students' mental models (BLINDED, 2023). However, as Thompson et al. (2016) apprise, these proposals do not offer definitive solutions to overcome the abovementioned difficulties. Furthermore, most of them lack explicit explanations of the design principles and decisions; and the evaluation of the quality is usually limited to students' gains. Therefore, this work aimed to iteratively and systematically design, implement, evaluate and refine an evidence-informed plant nutrition TLS for secondary education using the Design-Based Research (DBR) in order to empirically prove its effectiveness and make explicit the rationale behind the decisions (Easterday et al., 2014).

Key objectives:

The main objective was twofold: 1) to conduct interventional research that develops pioneering didactical knowledge and theoretical contributions; and 2) to deliver a ready-to-use didactical product of proven efficiency.

Research design and methodology:

Two iterative DBR cycles focused on upper secondary education were conducted over three years of research (Fig.1).

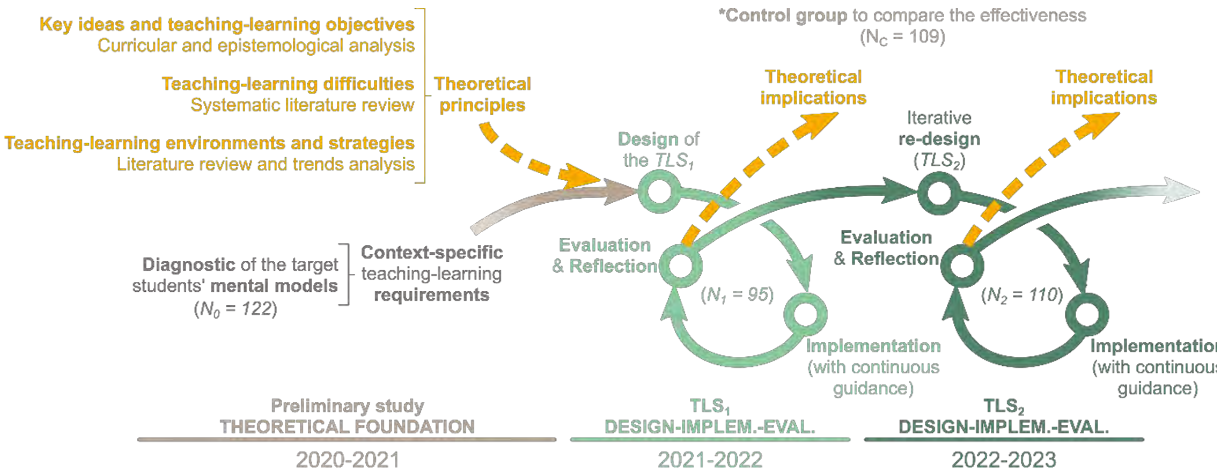

Figure 1. Overview of the study design.

In the first phase, the theoretical foundations (key ideas, objectives, difficulties, effective teaching strategies which integrate content knowledge and scientific practices, and context- specific learning demands) of the TLS were defined. In the subsequent design phase, the theoretical underpinnings described were explicitly connected through the construction of a set of activities (teacher-researcher negotiated TLSs). In this study, these TLS1&2 were designed using the Model-Based Inquiry (MBI) cycles described by Jimenez-Liso et al. (2022) that allow students to engage in inquiry and modelling activities. The third phase corresponded to the TLS implementation by teachers using the guide provided by the researcher. Finally, the last phase involved the retrospective examination regarding effectiveness and quality of the TLS employing different instruments (i.e. teacher's diary, students' workbooks, external observation protocols and pre-post

attitudinal and conceptual questionnaires that were analysed using phenomenography and Item Response Theory) which informed the iterative redesign of the TLS.
In total 436 students participated in this research. 122 students completed the diagnostic questionnaire in order to explore the context-specific conceptualization level and learning demands. 95 and 110 students underwent the preliminary TLS_1 and the redesigned TLS_2 respectively, and they were administered pre-post questionnaires that were adapted from the one used to diagnose teaching-learning difficulties. Finally, 109 participants belonging to the control group studied the topic via traditional lectures and textbooks and responded to the same pre-post questionnaires $TLS_{1\&2}$ students did.

Findings:
Students learning through the specifically designed TLSs, on average, achieved higher conceptualization levels and improved their mental models more than their control counterparts. Indeed, the mixed method analysis of the pre-post questionnaires elucidated that this significant shift was particularly remarkable in the case of the most demanding aspects of the SMPN, and that the evidence-oriented redesign of TLS_1 was successful to improve the effectiveness and quality of the TLS_2 (Fig. 2).

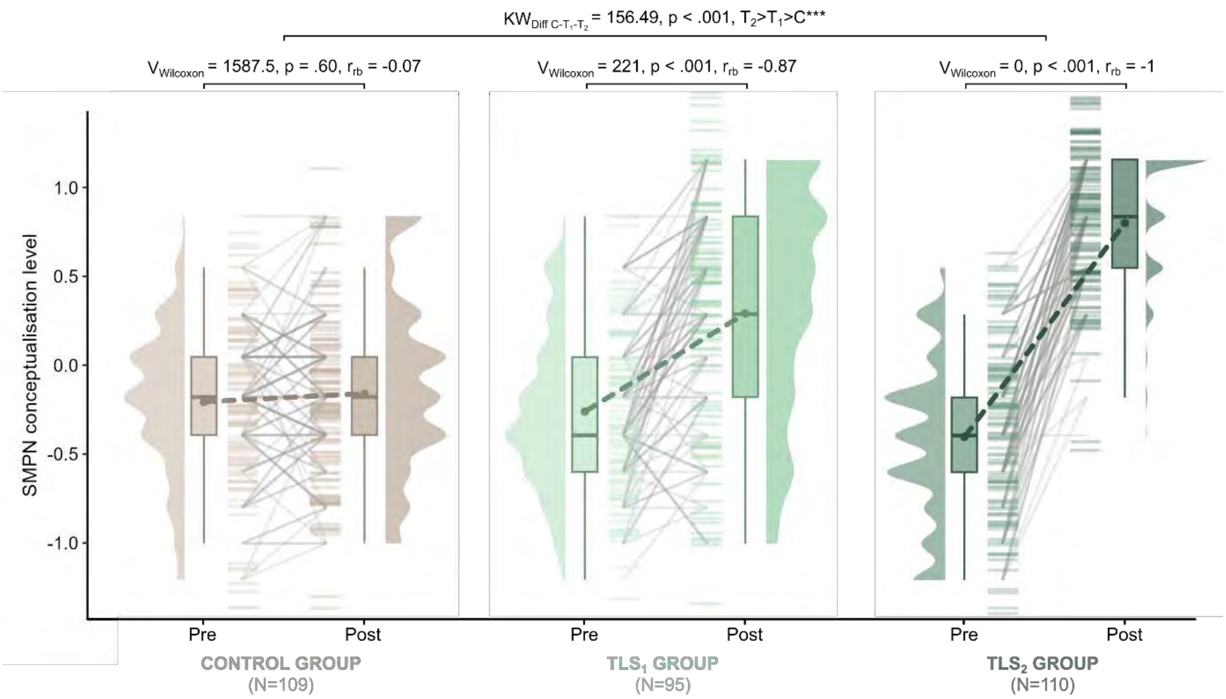

Figure 2. Results of the pre-post questionnaires showing the change on the SMPN overall conceptualisation level of the different cohort groups.

Furthermore, the retrospective analysis using the teachers' diary, students' workbooks and external observation protocol tools allowed to evaluate and certify the quality of the design principles of the TLS and the materials themselves. These assessment tools revealed that the experimental group students ($TLS_{1\&2}$) were permitted to hold discussions around their ideas during the inquiry phase and were provided opportunities to reflect on their mental models. Thus, these opportunities that did not take place in the more direct instruction approach of the control group may partially explain the success of the $TLS_{1\&2}$.

Conclusions:
This research evidences that: 1) the MBI approach seems to be a promising way for bringing students' mental models closer to the scientific consensus while they engage in scientific practices; 2) the DBR methodology provides a robust framework for designing, implementing, evaluating and improving TLSs while bridging the theory-practice gap. Indeed, this approach is not only useful to obtain an effective product but also, due to its iterative and introspective nature, enables to study the design decisions and principles analysing what activities or strategies work and why. Thus, regarding the teaching-learning of the SMPN, this study identified the importance of explicitly raising metacognitive awareness of students' intuitive ideas, considering their difficulties, tracing matter and energy, and providing them continued and scaffolded opportunities to revise their models through reflective practices.

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Teaching core biological concepts based on the cosmos evidence ideas model

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Theoretical background or rationale

The teaching of core biological concepts included in Ecology and Evolutionary Theory (ET) presents a number of difficulties, with the student's alternatives being the most prominent of them. Organization of inquiry-type activities within a Teaching Learning Sequence (TLS) is necessary for systematic educational interventions aiming at conceptual change (Meheut and Psillos, 2004; Psillos and Kariotoglou, 2016). Tselfes (2003) suggests that the Cosmos- Evidence - Ideas model (CEI), which is based on the Hacking Laboratory Classification (1992), might operate as a guide when choosing educational activities for the development of a TLS. According to this classification, the activities of laboratory sciences are defined by an almost independent "inner life" where Cosmos, Evidence and Ideas, three distinct entities, are always interacting and changing as a result of this interaction. Physical objects like the sample, data collection tools, and raw data are all covered in the Cosmos category. Evidence refers to all sorts of data that have undergone any type of processing. Theories, beliefs, theoretical notions and models are examples of Ideas. The model has been used as an assessment tool in previous studies (Psillos et al., 2004; Kallery et al., 2009), and its first implementation as a design tool gave encouraging results (Papadopoulou and Ntinolazou, 2019).

Key objectives:

The empirical studies in the field of science teaching, aiming at conceptual change, include a variety of teaching proposals. Each proposal results in design principles, depending on the aspect of teaching that the researcher considers most important. Regardless of the approach, the CEI model can guide the selection of the most effective activities. Its advantage is that it treats each teaching activity as a set of interactions of equal value. In this study, its potential to promote the weakening of students' alternative ideas and strengthening of the scientific concepts they use in their justifications is tested.

Research design and methodology:

Initially, a TLS of five teaching scenarios was designed for the basic concepts of ecology and another TLS of six teaching scenarios for evolutionary theory. The scenarios included inquiry- type activities that encouraged students to work in pairs or small groups. The initial TLSs were subsequently analyzed and modified to meet the design principles posed by the CEI model. Thus, two additional, revised TLSs emerged. All TLSs were implemented in different groups of the 3rd grade of a high school in Northern Greece, including 18 – 21 students each. Two pre- post questionnaires were created to evaluate learning outcomes, one for each field. Both had a similar structure: 8 multiple-choice questions and 3 open-ended questions.

The performance of students in initial and revised TLS before and after teaching was compared, as well as their performance before and after the teaching, for each thematic area separately. Parametric and non-parametric tests were conducted, depending on the characteristics of the sample in each case (normal distribution, homogeneity).

Findings:

For the basic concepts of Ecology

The students of both groups started from the same cognitive starting point for all the topics examined with the questionnaire and increased their performance in the multiple-choice questions, moderately for the group of the initial TLS and very highly for the group of the revised TLS. No statistically significant increase in open-ended question performance was observed in either group. However the difference in the final performance was statistically significant in favor of the revised TLS group.

Table 1. Quantitative results from the ecology TLSs application

Type of questions	**TLS 1**		**TLS 2**	
	Difference in Means	**Statistical significance meters**	**Difference in Means**	**Statistical significance meters**
Multiple choice	0,1181	p = 0.036, d = 0.534	0,2708	p = 0.000, d = 1.40
Open ended	0,000	p = 0.754.	-0,084	p = 0.819, d=0,055

For evolutionary theory

In this topic also, the two groups started from the same cognitive starting point and improved their performance in the multiple-choice questions, although not in a statistically significant way. However, statistically significant and very high was the increase in students' performance in the open-ended questions in both groups. The students in the group of the revised TLS were able to integrate more scientific concepts into their reasoning after the instruction (Table 3, concepts marked in bold), compared to the group of the initial TLS.

Table 2. Quantitative results from the evolution theory TLSs application

Type of questions	**TLS 1**		**TLS 2**	
	Difference in Means	**Statistical significance meters**	**Difference in Means**	**Statistical significance meters**
Multiple choice	0.025	p = 0.670	0,115	p = 0.087
Open ended	0.889	p = 0.000 < 0.05, d = 1.393	1.426	p = 0.000 < 0.05, d = 2.028

Table 3. Descriptive results from the evolution theory TLSs application

Concepts	TLS 1 group		TLS 2 group	
	pre	post	pre	post
Environment/different conditions	7	**11**	9	8
Heredity	1	5	3	4
Common descent	2	4	1	**8**
Time scale/evolution unit	1	2	1	7
Mutations	6	9	2	**12**
Genetic recombination	0	0	0	1
Random selection/genetic drift	0	0	0	3
Diversity	0	0	2	0
Natural selection	0	5	0	**14**

Conclusions:

To sum up, for both subjects included in the research, the CEI model gave positive results. Particularly, on the basic concepts of Ecology TLS's, the students in the group of the revised TLS performed better. As far as the TLSs for evolution are concerned, the qualitative data prove that the students in the group of the revised TLS benefited more from the teaching, although no statistical difference was found in their performances's increase. So, in relation to the central research question, it can be said that the use of the CEI model as a design tool for a TLS can enhance its effectiveness.

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Promoting vertical coherence when explaining human body phenomena.

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Theoretical background or rationale

One of the main traits of the biological explanation is that involves multiple and hierarchical organization levels. Hence, the explanation for, or mechanisms of, phenomena apparent at on scale often lie at a different scale level of (Schneeweiß et al., 2022). This trait poses a significant challenge for students, as their explanations of biological phenomena are frequently characterized by showing little connections between levels and confusion of levels, that is, a lack of vertical coherence (Jördens et al., 2016).

Visual representations (such as mock-up) can help students to reflect on how different organization levels are interconnected, reinforcing the vertical coherence of phenomena. Research on representations has indicated strong conceptual gains, especially when these representations are generated by the students and are conceived both as a process and product (Prain & Tytler, 2012). The role played from these representations is very well recognize since the old works of Bruner, Piaget or Vygotsky's where representations were identified as mediators between scientific knowledge and students' thinking, especially if the emphasis is shifted from learning from representations to learning with them (Tippett, 2016).

Key objectives

To analyses students' difficulties when developing biological explanation (that is, using micro- level interactions to explain macro-level phenomena), our research focuses on how students represent some human body phenomena. Key objectives are:

- Identify how different levels of organization are used to explain emergent phenomena using a mock-up.
- Analyze the role of cell level in students' explanation of emergent phenomena to explain external and internal environment interaction.
- Analyze students' evolution from their initial representation to the final ones within an activity.

Research design and methodology

300 students of the 3rd year of Bachelor's Degree in Primary Education enrolled in Science Education course were asked to construct a group mock-up to explain different emergent phenomena:

- How do food and drinks arrive at one of your arm's cell?
- How does air arrive at one of your arm's cell?
- How do your arm cellular waste products are removed?

This research analyzed a 5h activity at the beginning of the didactic sequence. After a group consensus activity about how they answer the question assigned, they start constructing their representation. The only explicit requirements that is given is that they must represent the cellular level (micro-level) where needed, having in mind that all our body is made by cells.

Teachers were interacting with students regulating their first representations.

Students were asked explicitly to represent a dynamic representation of those emergent phenomena, focusing on processes involved more than in anatomical aspects.

Each group has 4h to construct their representation and at the end, they explain their phenomena to the others using their representation.

Data from oral explanation, first individual and group drawing as well as the representation are analyzed using a qualitative approach.

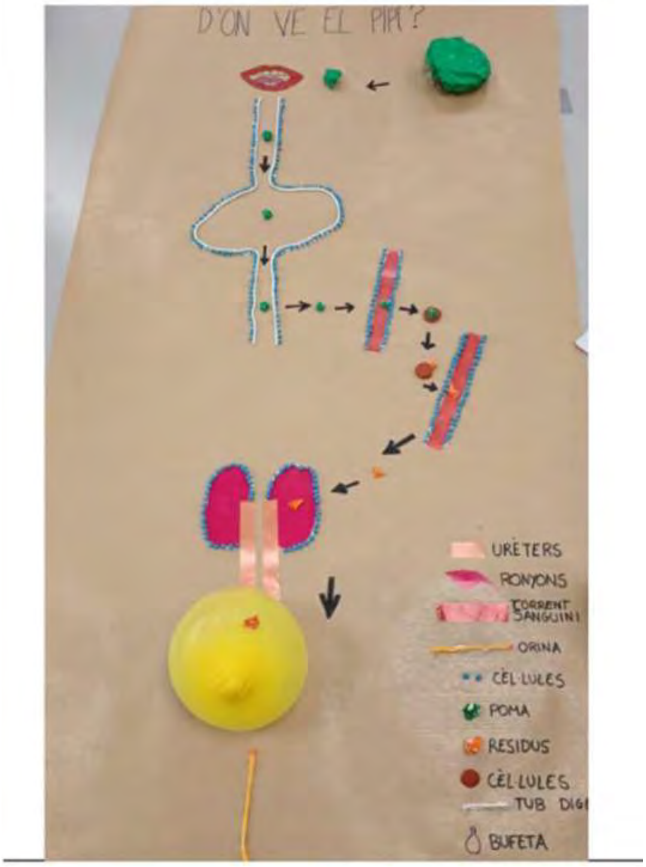

Figure 1: A mock-up about the body removal of cellular waste created by a group of students

Findings

Most of students' representations arei still more focused 0n the anatomical representation than in the process asked to represent. Even though they are explicitly asked to represent a process to answer an emergent phenomenon, they are more likely to represent it only as a pathway follow for nutrients or cellular waste. Micro-level interactions are dismissed, and teleological explanations are still presented (intestine choses what to absorbed)

Regarding students biological thinking evolution, we observe that at the very beginning of the activity students shows typical biological misconceptions defined in the literature: solid food waste related to feces, and drink waste to urine and lungs as the place where oxygen is converted to Carbone dioxide. Only a few of them represented the circulatory system and place the cell as the structure where nutrients and oxygen need to arrive. Anatomic structures are represented in a static way with few mentions to processes, and all of them in a teleological way).

All final representation incorporates circulatory system and cells, but with different roles. Preliminary results of how micro-level interactions are used to explain macro-level properties while analyzing students' representations, allow us to identify 3 different categories of cells' role:

- Cell as a structure that does not participate in the interaction. In these representations students use cells as part of the anatomic structure represented but are not used to explain interactions between external and internal environments. They still focused on the macro level properties and could not relate it to micro-level interactions.
- Cell as a structure that wraps up crucial anatomic structure represented but are not used to explain interactions between external and internal environments. They incorporate the micro level, but it is not used to explain interactions.
- Cells as the unit of the anatomic structure represented used to explain interactions between external and internal environments. Micro level is incorporated to explain how nutrients and waste products could move between the internal to the external environment.

Results regarding students' explanation are still being analyzed.

Conclusions

Incorporating microlevel interactions to explain macrolevel properties is not an easy issue for students but is crucial for understanding biological thinking. Using representations of emergent phenomena prompt students to focus more on the process involved and not only on the anatomic structure related.

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Roundtable

Diversity and Inclusion

Attitudes about gifted education among estonian basic school biology and science teachers

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Theoretical background or rationale
This study explored teachers' general attitudes toward gifted education and differentiated teaching. Research on this topic is essential because identifying gifted children and their educational needs is among the most important psychological and pedagogical problems, as it is generally assumed that to meet the needs of gifted students effectively, teachers should have a favourable view of the gifted (Troxclair, 2013). In addition, knowledge of teacher attitudes has been considered valuable in planning the implementation of gifted education and ensuring appropriate opportunities and educational interventions for gifted students (Cross, Cross & O`Reilly, 2018). Examining teachers' attitudes to promoting the education of gifted students is also essential because the behaviour of teachers and the way they teach depends on it (Lassig, 2009).

Research question asked:

1) What are Estonian basic school biology and science teachers' attitudes toward gifted education ?

Research design and methodology:
We invited Estonian biology and natural science teachers who teach 6th-9th grades to participate in this study.
We used Laine et al. (2019) instrument designed after Gagne and Nadeau (1991). The instrument contained 36 statements, and teachers rated their attitudes on a 9-point Likert scale ranging from 1 (strongly disagree) to 9 (strongly agree). The instrument was translated from Finnish, and we used an expert method to check the validity of the Estonian instrument. Two educational researchers and two teachers evaluated the comprehensibility of the questionnaire. The reliability of the questionnaire was Cronbach's alpha (0.8), and in the study, we used the six factors obtained by Laine et al. (2019) to describe teachers' attitudes.

At the suggestion of experts, we added two questions with open answers:
1) What are the three most important things that would need to be changed in Estonia's talent policy?
2) Which student is talented for you?
In addition, we asked for information on educational background, age, teaching experience, and gender. Most of the respondents were women (73%). The gender distribution was close to the national gender distribution of science teachers. 27% of the respondents had more than 31 years of work experience as a science teacher, 10% had 26-30 years, 16-25 years and 6-15 years, 22%. Only 19% of the respondents had up to 5 years of work experience; all had a pedagogical higher education.

Findings:
According to the results (Table 1), teachers generally supported gifted education, indicated by the mean of 7,0 (SD=2,31) on the *„Special support and social value"* scale. The mean of 4,6 (SD=1,26) in the *„Elitism"* scale was near the midpoint, indicating that the teachers had a neutral attitude toward the claim that gifted education is elitist. The mean of 4,5 (SD=1.22) for the scale *„Objections to supporting"* future indicates that teachers' attitudes were generally favourable toward the education of the gifted. The teachers were against the notion that „ gifted children might become vain or egotistical if given special attention*"*. The high mean of 6,4 (SD=1,19) on the scale *„Support for differentiation"* indicates that teachers highly support differentiated teaching for the gifted. Finally, the high mean of 6,6 (SD=1,58) on the scale
„Practical obstacles to serving gifted learners" indicates that the teachers viewed gifted education in regular classrooms as challenging. The biggest obstacles were that class sizes were too large (M=7.9; SD=1,48) and lack of time (M=7,9; SD=1,66). The teachers also indicated that identifying the gifted is difficult, especially among immigrant children (M=6,6; SD=2,20). One major obstacle identified by teachers was the lack of proper materials (M=6,5; SD=2,2). On the *"School acceleration"* scale, teachers tend to be negative about starting school early (M=4,2; SD=2,14) and skipping classes (M=4,4; SD=2,06).

Table 1. Assessing Attitudes of Science Teachers Toward Gifted (n=166)

	M(SD)	Mode
Scale1. Special support and social value	**7,0(2,31)**	
8. Gifted persons are a valuable resource for our society	8,6(1,52)	9
17. To progress, society must develop the talents of gifted individuals to a maximum	8,1(1,22)	9
9. The gifted need special attention in order to develop their talents fully	8.0(1,30)	9
1. Our school should offer special educational services for the gifted	7,9(1,50)	9
2. The best way to meet the needs of the gifted is to put them in special classes	6,6(2,13)	5
23. The leaders of tomorrow's society will come mostly from the gifted of today	5,5(2,22)	5
18. By offering special educational services to the gifted, we prepare the future members of a dominant class	4,5(2,40)	1
Scale 2. Elitism	**4,6 (1,26)**	
13. Gifted children should be left in regular classes because they serve as an intellectual stimulant for the other children	5,7(1,90)	5
14. By separating students into gifted and other groups, we increase the labelling of children as strong-week, good-less good, etc	5,3(2,51)	7
20. Average children are the major resource of our society, so they should be the focus of our attention	4,9(2,06)	5
4. Special educational services for the gifted are a mark of privilege	4,1(2,63)	1
19. Taxpayers should not have to pay for special education for the minority of children who are gifted	2,9(2,24)	1
Scale 3. Objections to support	**4,5(1.22)**	
11. It is parents who have the major responsibility for helping gifted children develop their talents	6,2(1,86)	5
16. The gifted are already favoured in our schools	4.9(2,38)	5
12. A child who has been identified as gifted has more difficulty in making friends.	4,4(2,28)	5
10. Our school is already adequate in meeting the needs of the gifted	3,6(1,81)	3
21. Gifted children might become vain or egotistical if they are given special attention	3,4(2,15)	2
Scale 4. Support for differentiation	**6,4(1,19)**	
26. The needs of the gifted can be addressed in regular classes through differentiation	6,8(1,94)	7
34. Gifted education should be carried out within our current comprehensive school	6,8(1,80)	7
29. It is the teachers' responsibility to differentiate teaching in a way that provides gifted students with learning experiences and challenges	6,5 (2,01)	7
27. We should address the giftedness of those children who simultaneously have learning difficulties and/or behavioral problems	6,3(1,80)	7
28. We need to address the needs of the gifted, but this can be done in regular heterogeneous classes	5,7(2,01)	7
Scale 5. Practical obstacles to serving gifted learners	**6,6 (1,58)**	
36. Teachers' lack of time and haste inhibit supporting giftedness in regular classes	7,9(1,66)	9
32. Class sizes that are too large inhibit the education of the gifted in regular classes	7.9(1,48)	9
30. It is hard for teachers to identify giftedness among immigrant students	6,6(2,20)	9
35. The lack of proper materials inhibits gifted education in regular classes	6,5(2,20)	8
31. It is hard for teachers to identify giftedness among students who have learning difficulties or behavioral problems	6,1(2,24)	8
33. It is hard for teachers to identify giftedness in children	4,5(2,30)	7
Scales 6. School acceleration	**4,3(2,18)**	
24. A greater number of gifted children should be allowed to skip a grade	4,4(2,06)	5
5. It is more damaging for a gifted child to waste time in class than to adapt to skipping a grade	4,4(2,35)	5
25. Starting school one year earlier could be beneficial for gifted pupils	4,2(2,14)	5

The most frequent answer to the question *"Which student is gifted for you?"* was that a gifted student is capable (48 times, 28.92%). The ability category includes the student's skills to analyse, relate, and infer. Opinions were widespread among teachers if the gifted student is interested in learning (44 times, 26.51%), is broad-minded and intelligent (41 times, 24.70%), acquires knowledge quickly (29 times, 17.47%), is curious (29 times, 17.47%). A gifted student is creative (18 times, 10.84%), motivated (17 times, 10.24%), knows how to apply his knowledge (14 times, 8.43%), has quick thinking (13 times, 7.83%), and is self-directed (13 times, 7.83%).

The question "*What are the three most important things that need to be changed in Estonia's gifted policy?"* received many different answers from teachers. However, 29.52% of 166 teachers believe providing teachers with support materials for dealing with gifted students is essential. In this category, the teachers pointed out that creating additional materials and their availability are necessary. Teachers consider it essential to reduce their general workload (38 times, 22.89%), find additional funding (28 times, 16.87%), and train and support teachers on how to support talented students (25 times, 15.06%)
Studies have found that acceleration and ability-based grouping are the most effective intervention methods for supporting gifted students (Hattie, 2009; Wood, Portman, Cigrand, & Colangelo, 2010). According to our study, teachers are more likely to have a negative attitude toward acceleration and a positive attitude toward differentiation. Unlike Finnish teachers (Laine et al.2019), Estonian teachers support the creation of special classes for gifted students.

Conclusions:
Science teachers' attitudes towards gifted students and their support are mostly positive. But they did not support the idea of gifted entering school earlier. In general, teachers believe schools should offer more support to gifted students.
According to biology and science teachers, developing a gifted education policy is essential for Estonian society.

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Following the APA 7th style

Making the invisible of photosynthesis visible for young immigrant and non-*immigrant students using augmented reality*

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How can serious games help us make visits to extracurricular learning sites more inclusive?

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Theoretical background or rationale
Extracurricular learning sites extend the possibilities of biology didactics beyond the boundaries of classroom teaching and create new perspectives and approaches for both students and teachers. In addition, they can have a positive impact on motivation and may ultimately support the success of learning (Potvin & Hasni, 2014). Especially in biology, extracurricular learning sites are a place for experiencing nature. Therefore, one of the many potentials of these activities is to aim for affective learning objectives (Favre & Metzger, 2013).

With the increasing consideration of inclusion in education, the topic is also gaining importance for extracurricular learning sites. To create successful learning environments for everyone, the basic needs (Deci/Ryan, 2012) must also be met in museums, zoos and other places, taking into account individual characteristics of each visitor. Accordingly, it is necessary to analyse both physical and content-related barriers and challenges at extracurricular learning sites of biology.

Serious games are games designed with a purpose other than pure entertainment (Breuer & Bente, 2010). They are similar to extracurricular learning sites in that they open up multiple approaches to topics and expand the possibilities of classical school teaching. Serious games are often researched with regard to their motivational performance (e.g., Hoblitz, 2015), but rarely related to their potential for inclusive design (Patzer et al., 2018; Hersh & Leporini, 2018). It therefore remains an open question whether a combination of the concepts of visiting extracurricular learning sites and serious games (e.g., as pre- or post-visit activities) can help making learning sites more inclusive.

Key objectives:
In its first phase, the study investigates strategies of extracurricular learning sites in dealing with heterogeneous learning groups. The central questions are: Which aspects of inclusion or which individual characteristics of their visitors are particularly challenging for the employees of learning sites? What strategies do the learning sites use to take the individuality of their visitors into account? Do learning sites use digital methods especially aimed at inclusion (or are they willing to do that)?
The answers to these questions, among others, will lead to the development of a serious game in the second phase of the research project. After this, another question arises: To what extent can a serious game designed with the contents of an exemplary learning site in mind, in combination with a visit, help individuals in heterogeneous learning groups achieve the learning goals?

Research design and methodology:
For the study, employees of different out-of-school learning sites were interviewed (n=25). The interviews were conducted on-site or via video conference and ranged in length from 19 to 38 minutes. The underlying guide consisted of 15 items. Some questions were related to the learning objectives of the particular learning site, other focussed on aspects of inclusion.
The interview guide was piloted in the summer of 2022, afterwards inquiries were made to randomly selected out-of-school learning sites in Germany with biological content. The evaluation of the interviews followed the procedure of qualitative content analysis according to Mayring (2022).

Findings:
An analysis of the material available (n = 25) indicates that the extracurricular learning sites, in their self-assessment, are mostly successful in taking physical limitations into account in their educational work and in enabling most of the visitors to have affective access to nature. It is however perceived as difficult to convey subject content to learners with different language levels or prior knowledge.
Most of the interviewees were very interested in using digital media (such as serious games) for inclusive education. However, they preferred to give out such products to schools for pre- or post-visit preparation. Use during the learning unit on site was viewed more critically because it would diminish the nature experience.
Technical limitations on site, which make the use of digital media more difficult, and low technical knowledge of the staff were also mentioned.

Conclusions:

Knowledge about the primary inclusion challenges at extracurricular learning sites allows for the targeted development of concepts and learning products that can be used to improve learning success. However, studies on barriers and challenges based on empirical surveys are still a research gap. With the results of the study, more detailed statements can be made.

The results of this evaluation can be the foundation for further research on the potential of the combination of out-of-school learning and follow-up activities through serious games. The results of the interview were included in a catalogue of criteria that should be considered in the development of serious games in the context of out-of-school learning.

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Diversity, Genetics and Ethics: Addressing racism in teacher education

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The perspective of (non-) special needs pre-service biology teachers on inclusion

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Biology instructors’ understanding of effective and inclusive teaching at a minority serving higher education institution in the US

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> “We deliver academic excellence by pursuing knowledge, inspiring creativity, supporting our diverse community and advancing social justice and positive change in the world.” (October 2023)

This is the current mission statement of a minority serving higher education institution on the West Coast of the United States. A social justice oriented reading highlights the quality of teaching and learning to be characterized by a diverse learning environment. In this sense, diversity, creativity, and community are understood to be at the core of socially just and excellent academic education. Despite a US-wide shift towards mission statements and policy changes explicitly including dimensions of equity and social justice, changing academic biology teaching towards creating more equitable and socially just learning spaces has proven to be an ambitious goal and shown to be more easily put into writing than practice (Author, 2012).

The institution’s biology department has implemented a variety of interventions to work towards the goal of providing excellent, effective, and inclusive education to its diverse student body. At the core of this program is the professional pedagogical development of biology instructors, supporting them to collaboratively develop and implement evidence-based and inclusive teaching methods (Author, 2018). One intervention is a week-long *Teaching Institute* which includes activities that explicitly conceptualized scientific teaching as based on active learning, assessment, equity, and diversity, and the collection of classroom evidence to iteratively improve biology teaching and learning. Starting in 2013, only four years later, nearly 90% of the university’s biology instructors had participated in the professional pedagogical development interventions. This makes this department a rather unique context to explore the effects of interventions. Here, we explore instructors’ self-reports on how their conceptualizations of effective and inclusive teaching have changed over time and if and how these changes were prompted by interventions. Theoretically rooted in sociocultural understandings of learning, we consider learning to be intertwined with processes of identity negotiations and situated in the environment that participants find themselves in (Holland and Lachicotte, 2007; Lave and Wenger, 1991). This also applies to instructors’ process of learning to teach in a given environment, constituting a process of becoming, influenced by and influencing instructors’ identity work.

Key objectives
To better understand barriers and affordances of departmental pedagogical change and development opportunities, we ask, 1) How do biology instructors at SFSU conceptualize effective and inclusive teaching, 2) How have their self-reported conceptualizations about effective and inclusive teaching changed over time, and 3) How have these conceptualizations been influenced by professional development interventions?

Research design and methodology
Addressing these key objectives, we designed a semi-structured interview study (Husband. 2020), conducting two interviews with 22 biology instructors. The *first interview* was either online or in person (if requested) and covered objectives one and two discussing how instructors define effective and inclusive teaching, how they translate those conceptualizations into their classrooms, as well as how their conceptualizations and teaching have changed over time. We allowed for reflections on the instructors’ personal backgrounds if they were brought up during the interviews, and how instructors described them as influential to their professional practices and perspectives on learning and teaching.
For the *second interview*, we invited instructors to meet the interviewer in a space of their choice which had an impact on their perspective on inclusive and effective teaching. During interviews we discussed the impact of the respective spaces, what changes the spaces prompted or inhibited. Furthermore, we explicitly addressed objective three discussing if and how professional interventions have shaped instructors’ teaching perspectives and practices. Depending on how the conversations evolved, some questions were covered earlier or later during interviews.

The majority of the interviewees participated in the first two *Teaching Institutes* facilitated at SFSU (20 instructors, 91%), 7 (32%) identify as women and gender non-binary, 15 (78%) as men. Furthermore, about half of the interviewees self-identify as people of color while the other half self-identifies as white. In order to protect participants' anonymity, we refrain from disclosing more detailed demographic information. All interviews were transcribed using a transcription service and analyzed using the analysis software NVivo.
To get an overview over the data, we first conducted a thematic analysis (Braun and Clarke, 2012) with an epistemological sensitivity towards how teaching conceptualizations intersect with participants' identity negotiations. We here built on Carlone and Johnson's (2007) pillars of science identity, namely competence, performance, and recognition. While we here present preliminary findings, we will further refine our analysis in a reiterative process and present final results at the conference.

Preliminary findings
A first analysis indicates a variety of ways in which instructors conceptualize effective and inclusive teaching. One approach is 1) *content-centered* and effectiveness and inclusivity based on if predefined content was communicated effectively and made available to everyone. A 2) *relevance-centered* approach makes content relevant and thereby accessible to students, as well as to actively include students in the development of the teaching and classroom activities.

Motivations for these approaches are in line with what Author (2012) described, namely that a lack of training, time, and incentives are central to prohibiting pedagogical change. However, the epistemological sensitivity for identity made visible that these understandings are deeply interwoven with instructors' identity work. Instructors who are *content-centered* tend to display a strong research identity and see this identity to be challenged when the teaching focus shifts to pedagogies. When drawing on a *relevance-centered* approach, instructors show a tendency to share about their experiences feeling marginalized during their educational career as well as feeling reassured that they are valued for the teaching they do and that their perspectives matter. Furthermore, they report that the professional training interventions provided them with language for strategies they already were familiar with, which reassured them in their science teaching identity.

In the conference talk, we will further expand on these findings as well as contextualize them in the broader landscape through interactive discussions.

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