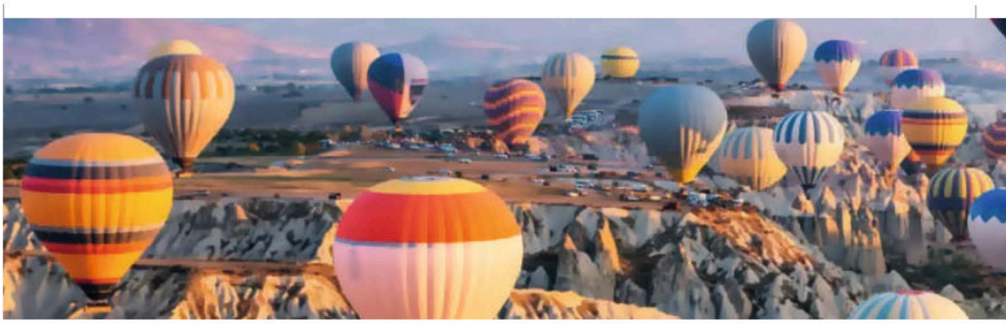

ESERA 2023 Cappadocia

The 15th EUROPEAN SCIENCE EDUCATION RESEARCH ASSOCIATION ESERA

Proceedings Book Series-IV

Editors
Orhan Curaoglu
Gokhan Kaya
Metin Sardag
Bahadir Altintas

nobel bilimsel

The 15th Conference of the European Science Education Research Association (ESERA)

Proceedings Book Series-IV

Strands 9, 10, 11

ESERA 2023 Conference
Cappadocia, Türkiye
August 28- September 1, 2023

Editors:
Orhan Curaoglu, Gokhan Kaya, Metin Sardag, Bahadir Altintas

Foreword

It is my pleasure to introduce the proceedings of the 15th Conference of the European Science Education Research Association (ESERA) in Cappadocia, Türkiye. The conference was the first physical conference following the Covid-19 pandemic, and as such it was a wonderful opportunity for the ESERA community to reconnect in person and to learn about our respective research across Europe and beyond. I am particularly delighted that ESERA was able to provide a platform for early career researchers and new members who joined the ESERA family during this conference. Based on my interactions with the community at the conference, the event was intellectually stimulating and socially pleasant experience for all.

The planning of the conference began when we were still in the midst of the pandemic, slowly emerging from a very challenging period globally. The three universities involved in the organisation of the conference - Hacettepe University, Gazi University, and Nevşehir Hacı Bektaş Veli University - provided enormous support throughout but it is important to note particularly the period following the devastating earthquakes in February 2023. On behalf of the ESERA Board and the ESERA community, I thank the leadership of the Local Organising Committee, namely Gultekin Cakmakci, Mehmet Fatih Tasar, and Mustafa Hilmi Colakoglu for the effective management of the preparations under such extraordinary circumstances.

The theme of the conference was “Connecting Science Education with Cultural Heritage”, one of the main goals of UNESCO, the United Nations Educational, Scientific and Cultural Organization. As a culturally diverse country with a rich heritage, Türkiye provided a brilliant context to consider research in science education in diverse social learning environments.

The five books of the conference proceedings have been edited by Gokhan Kaya, Metin Sardag, Mehmet Sogut, Tugba Ecevit, Kibar Gul, Orhan Curaoglu, Bahadir Altintas and Ismail Donmez. We acknowledge and thank them for their editorial input into the ESERA 2023 conference proceedings.

I hope that the conference proceedings will serve not only as a memory of a useful conference but also a forum where the newly established professional networks can flourish further, and help enhance our understanding of improving science education through research.

Sibel Erduran

ESERA President (2019-2023)

University of Oxford, UK

Foreword

A very warm welcome to the European Science Education Research Association (ESERA). The preparation for the conference began more than 2 before the conference. We received around 1300 submissions. After a review process, we had 695 Papers, 54 Symposia, 2 Panels, 20 Workshops, 150 Posters with 3 plenary speakers and 2 ESERA community plenary speakers. With on-site registration, there were around 1100 participants. After a review process, 195 manuscripts were accepted to be part of these five eProceedings.

As always ESERA supports early-career researchers. We think that everything needs to be done to keep their enthusiasm fresh and alive for developing a science education culture. Drawing upon that we had five workshops for early-career researchers and practitioners as part of the programme for the ESERA 2023 conference. That brings fresh enthusiasm to the new and young generation of researchers and practitioners in STEM education around the globe. Providing opportunities for early-career researchers to serve on the editorial board for the development of these five eProceedings is one of the outcomes of that initiative.

Spanning Europe and Asia, it can be said that Türkiye has been the meeting place of many peoples and cultures throughout the centuries. Having colleagues from over 65 countries at this conference in Cappadocia, a historical region in Central Anatolia, enabled us to show our way of mutual understanding, respect, and cooperation which is also much needed in today's world. Accordingly, the theme of the ESERA 2023 conference was "Connecting Science Education with Cultural Heritage".

The ESERA 2023 conference was a great success with all conference participants and science education around the world. These five eProceedings will allow us to further debate in the field. We look forward to these valuable interactions and experiences, developing partnerships, and significant outcomes of the conference.

On behalf of the Local Organizing Committee of the ESERA 2023 Conference, I would like to thank everyone who has contributed to this conference and eProceedings in different capacities.

Looking forward to seeing you all at the ESERA 2025 Conference in Copenhagen, Denmark!

Gultekin Cakmakci

ESERA 2023 Conference President
Hacettepe University STEM & Maker Lab, Türkiye

Connecting Science Education with Cultural Heritage

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The Proceedings of ESERA 2023 is an electronic publication for revised and extended papers presented at the ESERA 2023 conference in Cappodocia, Türkiye during the August 28- September 1, 2023. All papers in the eProceedings correspond to communications submittedand accepted for the ESERA 2023 conference. All proposals to the conference went through a blind review by two or three reviewers prior to being accepted to the conference. A total of 695 papers, 54 symposia, 2 panel, 20 workshops, 150 posters were presented at the conference and in total 195 papers are included in the eProceedings.

The authors were asked to produce updated versions of their papers and take into account the discussion that took place after the presentation and the suggestions received from other participants at the conference. On the whole, the eProceedings presents acomprehensive overview of ongoing studies in Science Education Research in Europe and beyond. This book represents the current interests and areas of emphasis in the ESERA community at the end of 2023.

The Proceedings book series divided five different books eighteen parts that represent papers presented across 20 strands at the ESERA 2023 conference. The stand chairs for ESERA 2023 co-edited the corresponding part for each strand 1 to 20 and. All formats of presentation (single oral, interactive poster, ICT demonstration/workshop and symposium) used during the conference were eligible to be submitted to the eProceedings.

The co-editors carried out a review of the updated versions of the papers that were submitted after the conference at the end of 2023. ESERA,the editors and co-editors do not necessarily endorse or share the ideas and views presented in or implied by the papers included in this book.

The appropriate APA style for referencing this *Proceedings Book Series-IV* is as follows:

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Editorial

We are delighted to introduce the forth volume of the Proceedings Book Series for the ESERA 2023 Conference. This volume brings together an inspiring collection of research studies that were presented under three significant strands of the conference: Science Education for Sustainability, Agency and Futures Literacy (Strand 9), Environment, Health and Science Education (Strand 10), and Informal, Non-formal and Out-of-school Science Education (Strand 11).

As we navigate through the challenges of the 21st century, the role of science education in fostering sustainability, health, and lifelong learning is more critical than ever. The diverse topics and innovative methodologies showcased in these studies reflect the dynamic and evolving nature of science education across different contexts and communities.

Strand 9: *Science Education for Sustainability, Agency and Futures Literacy*

In this section, 12 in-depth studies explore how science education can empower individuals and societies to engage critically and creatively with global challenges. This strand highlights the importance of cultivating futures literacy—an essential skill set that enables learners to anticipate and shape future scenarios. The contributions here underscore pathways to nurture agency among learners, equipping them with the knowledge and confidence to contribute to a sustainable future.

Strand 10: *Environment, Health and Science Education*

This strand presents 8 comprehensive studies that bridge the intersections of environmental science, health, and education. The research featured under this strand emphasizes the integral role of science education in promoting public health and environmental stewardship. These studies investigate innovative approaches to teaching and learning, aiming to foster deeper understanding and commitment to ecological and health-related issues.

Strand 11: *Informal, Non-formal and Out-of-school Science Education*

Here, 10 studies delve into the diverse and dynamic realms of informal and non-formal education, as well as out-of-school learning environments. This strand highlights the significant impact of learning that occurs outside traditional classroom settings, be it through museum visits, science festivals, community projects, or digital platforms. These explorations offer valuable insights into how informal educational practices can complement formal science education and contribute to a lifelong love of learning.

Together, these strands form a comprehensive picture of the current trends and future directions in science education. They emphasize the urgency of integrative and holistic approaches to education that not only address immediate academic goals but also prepare learners to meet future societal and environmental challenges.

We extend our deepest gratitude to all the researchers, educators, and practitioners whose dedicated work is represented in these proceedings. Their commitment to advancing science education is a testament to the vibrant and collaborative spirit of the ESERA community. We hope this volume will serve as a valuable resource for educators, researchers, and policymakers, inspiring continued innovation and collaboration in the field of science education.

Warmest Regards,

Orhan Curaoglu, Gokhan Kaya, Metin Sardag, Bahadir Altintas

Hacettepe STEM & Maker Lab

August 2024

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Strand 9

Science Education for Sustainability, Agency and Futures Literacy

Antti Laherto & Eliza Rybska

Strand Chairs/Co-editors

Foreword

The chapter titled Science Education for Sustainability, Agency, and Futures Literacy in the ESERA 2023 proceedings brings together a collection of papers that address some of the most pressing issues of our time. In an era marked by rapid environmental changes, societal challenges, and uncertainties, the role of science education in fostering sustainable futures cannot be overstated. This chapter explores how science education can empower individuals and communities to engage with the complexities of sustainability, develop agency, and cultivate the capacity for futures literacy—an essential skill set for navigating the unknown.

Within this chapter, the authors present research that delves into diverse strategies, pedagogies, and conceptual frameworks aimed at equipping learners with the tools they need to critically engage with sustainability challenges. These contributions highlight how education can move beyond simply conveying knowledge, focusing instead on nurturing the skills, values, and attitudes that foster transformative action toward a sustainable future.

The 11 proceedings in this chapter span a broad range of themes, including curriculum innovation, the integration of sustainability into science education, and the development of learners' agency and futures thinking. Collectively, these studies reflect a commitment to advancing science education that is responsive to both present and future needs, promoting not just awareness, but meaningful change.

As you engage with the work presented in this chapter, we hope you are inspired by the innovative ideas and research-driven approaches showcased here. It is through such contributions that we can continue to push the boundaries of science education, ensuring it remains a key driver for a sustainable, just, and equitable future.

Promoting Secondary Students' Understanding of Sustainability Issues in Science Education by Utilizing Actor-Network Maps in the Frame of Research-Informed Action Projects

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Sustainability issues of our time, such as global warming, are often closely linked to developments in the fields of Science and Technology and particularly the ways powerful groups influence them to better serve for-profit purposes. We advocate that science education can potentially play a notable role in facilitating the equitable resolution of such problems by incorporating aspects of Environmental and Sustainability Education, thus promoting young citizens' awareness, critical thinking skills and action competence. We particularly focus on a key strategy of our work with students, the creation of Actor-Network maps, which is an adaptation of Actor-Network Theory (ANT) in the context of sustainability. We utilise ANT maps as analytical tools that facilitate students' understanding of the interactions between actants in the frame of the complexities of sustainability issues. In this paper, we explore how ANT maps can be evaluated and the ways that they have contributed to students' research processes. To do so, we have created and trialed an evaluation rubric, which we present alongside with our insight on the benefits and limitations of ANT maps in terms of students' knowledges on sustainability issues.

Keywords: Science Education, Sustainability, Qualitative Methods

Theoretical Background

As education has evolved in a time of socio-ecological crisis, a significant proportion of science education professionals, have emphasized the importance of developing educational skills that will promote a pedagogical bridge to common life. Their main aim has been to facilitate citizens' participation in knowledge production and decision-making (Hodson, 2011) in relation to harms that Science and Technology has been associated with. During the 70s and 80s, changes in social realities, such as the environmental movement among others, led to the creation of a movement of science education professionals, called STS (Science-Technology-Society), which demanded a more holistic science education (Aikenhead, 2003). Soon thereafter, "E" was added to STS to form STSE (Science-Technology-Society-Environment), thus marking the incorporation of environmental issues (Pedretti & Nazir, 2011). The aforementioned trend in Science education has been interacting and sharing common concerns with Environmental and Sustainability Education for many years.

In this paper, we argue that STSE frameworks can facilitate to promotion of genuine sustainability awareness in secondary science education. Therefore, we report on the application of a teaching strategy inspired by STSE with the intention to promote the goals of Environmental and Sustainability Education. The framework that we have adapted and utilised is called STEPWISE (Bencze, 2017), which stands for Science & Technology Education Promoting Wellbeing for Individuals, Societies & Environments. It consists of three phases in which students express existing subject knowledge on socio-scientific issues (Reflection phase); develop suitable research skills, knowledge and attitudes (Teaching phase); and conduct their own open-ended Research-informed Actions (Practice phase). A key characteristic of STEPWISE's structure, which is also shared with other European (Simonneaux & Simonneaux 2009) and international approaches (Zeidler & Nichols 2009) in science education is the process of de-punctualisation (Callon, 1990) of science and technology.

De-punctualisation refers to the process of unveiling the complex network of social relations that are part of problematic situations in science, parts of which are often hidden in education. A useful way to conceptualise de-punctualisation is through the lenses of Actor–Network Theory (ANT) (Latour, 2005). The perspective that the theory poses is that socio-technical issues (e.g. GMOs) consist of a variety of actants (human, non-human and symbolic ones) which connect and/or interact with one another, forming complex networks and alliances. These alliances are also called dispositifs (Foucault, 2008) and they can have different interests, often conflicting ones. De-punctualisation is a process that a researcher (e.g. scholar, teacher, student) can undertake to expose the non-visible aspects of such issues by mapping the components and relationships of alliances. This can then be followed by political and/or technical suggestions to improve a given situation (Gehl, 2016, p. 37–38). We think that de-punctualisation should be an important aspect of science education because an essential part of evaluating the critical decisions that affect sustainability is the understanding of the broad network of actants that are part of such issues (Irish & Romkey, 2021) multidisciplinary engineering program. In the course, Actor Network Theory, which is a method for analyzing sociotechnical issues with an emphasis on the concept of power and its distribution, was introduced to the students through a series of learning activities and an assignment, initially encouraging the students to apply the approach to a system within their own life. Subsequently, the approach was used to analyze complex sociotechnical issues, for example, the use of Coal-based energy in Nova Scotia, and the Coastal Gaslink pipeline dispute in the Wet'suwet'enterritory. This paper describes our approach to introducing Actor Network Theory to engineering students, the benefits and limitations of the approach, and the efficacy of the approach for exploring sustainability issues. Other instructors may consider the introduction of ActorNetwork Theory through courses in Engineering & Society and Engineering Design.”,”container-title”:”Proceedings of the Canadian Engineering Education Association (CEEA, Furthermore, de-punctualisation of sustainability issues should involve the exploration of the multiple dimensions (e.g. social, environmental economical) in which actants interact, therefore the acquisition of knowledge is likely to be more comprehensive. In this paper, we argue that science education approaches that would incorporate de-punctualisation are likely to explore in more depth the multiple dimensions of sustainability issues.

The novelty that de-punctualisation (and ANT) brings to science education is that it puts forward the dynamic relationships between a variety of actants, human as well as non-human ones. The importance of considering non-human actants as equally important as human actants has been emphasized by Pierce (2013, p. 112-15), who argued that in our time that the human genome has been mapped, *the boundaries between “nature”, “human imitations of nature” and humans have collapsed completely.* Furthermore, key nonhuman actants such as genes, cells, strands of DNA have now become data, that are patented and managed by experts (genetic scientists, government officials, industry experts) creating privately owned commodities (e.g. GMOs, pharmaceutical products) that are changing our world profoundly. Therefore, it is important to appreciate that non-human actants are not passive recipients but they meaningfully take part in the complex network of relationships that shape our world. This view aligns with the literature of Environmental and Sustainability Education that has challenged the distinction between the natural and manmade environment on the grounds that its urban, industrial, agricultural, natural, wild and virgin components are interdependent and interact through complementary and antagonistic relationships (Flogaitis, 2011b:142). Thus, it becomes a common premise between the two fields that in order to promote a democratic and sustainable future, students and citizens need to develop an understanding of the relation between humans and non-human actants.

In this paper, we claim that students can expand their understanding of sustainability by de-punctualising products of science and technology relevant to the curricula. As part of students’ work, this can be accomplished by creating ANT maps that depict the study of interactions between actants. We chose ANT maps because of the general importance of the strategy of concept maps in facilitating the awareness of sustainability issues, which is evident in recent years of environmental education research (Flogaitis et al., 2021, p. 173–214). We think that by infusing principles of ANT into sustainability education practices, such as concept mapping, we might facilitate students’ understanding of the complexity and the dynamics of natural, social, and economic systems.

However, to our knowledge, there is no literature on the assessment of ANT maps about sustainability education. This led us to our research questions: How can we evaluate an ANT map? If and how designing ANT maps promotes the understanding of sustainability issues?

Research context and methods

This paper reports on specific findings of wider Action Research (Carr & Kemmis, 2003) that has been conducted during the academic year 2022-2023. The research took place in a mixed-ability year 8 (age 12-13) science class at an independent British school in Athens. The class consisted of sixteen students, nine boys and seven girls. Throughout the autumn term, students engaged in preparation activities that helped them develop research skills and an understanding of sustainability. During the winter and spring terms, students conducted a project on social and environmental issues of their own choice. These issues related to topics that arose from the teaching of Chemistry and Biology. More specifically, the topics that emerged from the Chemistry unit "Combustion" were "electric cars: and "extreme weather events". Concerning the Biology unit "Breathing and Respiration" the topic that came up was "smoking". During students' project work, they worked in pairs and created eight ANT maps. In terms of data collection, we focused on students' ANT maps, the teacher's diary and interviews.

Concerning the use of ANT maps, we adapted ANT theory to adjust the process of de-punctualisation in the context of sustainability. To do so, we used the triple venn diagram of the sustainable development framework as a basis for ANT maps. Each of the three cycles illustrates one of the fields (societies, economies, environments), which provides students the opportunity to, firstly, identify the fields and clarify their meanings. Secondly, the visual representation of the overlaps between the three fields provide space where students can begin to consider how actants belong/function within multiple dimensions. Thus, our intention has been to scaffold the understanding of the interactions between science and technology with the different fields of sustainability (societies, environments, economies). Nevertheless, we need to point out that we are critical of the unclear and contentious uses of the term "sustainable development" -as well as the specific diagram- by powerful economic institutions such as the World Bank, which attempt to mask the gap between the opposing worlds of the economy and the environment (Flogaitis, 2011a, p. 69). Although we consider clear-cut distinctions between the three fields of sustainable development as problematic, we think that the diagram might offer a useful step - suitable for the students' age group - in organising sustainability concepts, while the overlapping fields continue to render visible that spaces that are actually full of meanings and processes. Regarding the analysis of data, ANT maps and students' interviews were analysed using an evaluation rubric (that we will present next) and content analysis, respectively.

Results, discussion and scholarly significance

To answer our first research question referring to the way that ANT maps can be evaluated, we have used ideas from concept mapping evaluation (Coutinho, 2014) to create an evaluation rubric of our own design. It consists of the following five criteria (Table 1): structure; content; relationships; alliances (dispositifs); place "me" within the map.

Table 1. Description of ANT map criteria

Criteria	Description
Structure	The degree to which the map is "weblike" and extends to all sections and intersections
Content	The degree to which the number and variety of actants depicts the complexity of the topic and the understanding of key concepts
Relationships	The extent that the map illustrates valid relationships/interactions between actants
Alliances (dispositifs)	The extent to which the map groups together actants that share common interests; outlines messages that describe the goals of the alliances
Place "me" within the map	Whether students placed and connected themselves within their map and with other actants

Furthermore, we expanded each criterion into three levels (exceed standard; adequately meet standard; below standard) (Table 2.). We chose to use a qualitative approach as we think that it aligns better with the subjective nature of how sustainability issues can be illustrated on ANT maps. Also, our intention through this process was to facilitate our understanding of students' thought processes rather than to utilise the maps as an assessment tool.

Table 2. ANT map criteria by level of categorisation

CRITERIA	Exceeds Standard (2 points)	Adequately meets standards (1 point)	Below Standard (0 points)
Structure	Map is very well designed with a "weblike" structure Extends towards all sections including intersections	Map is well designed, some concepts can be unconnected / some sentences are used to describe meanings Extends towards most sections including intersections	Map is choppy and confusing with unconnected concepts / many sentences are used to describe meanings There are gaps in some sections/intersections
Content	Identifies many key actants relevant to the topic of research (crosslinks) Contains a wide variety of actants including non-humans and semiotic actants Actants are well defined, distinct and related to the specific topic	Identifies some key actants relevant to the topic of research (crosslinks) Contains a fair variety of actants including non-humans and semiotic actants Some actants are well defined, distinct and related to the specific topic	Identifies a few or no key actants relevant to the topic of research (crosslinks) Contains a poor variety of actants A few or no actants are well defined, distinct and related to the specific topic
Relationships	Many arrows show relationships between actants within and across the fields of sustainability All relationships are valid Many key actants identified through crosslinks	A fair number of arrows show relationships between actants within and across the fields of sustainability Most relationships are valid Some key actants identified through crosslinks	There are a few or no arrows that show relationships between actants within and across the fields of sustainability A few or no relationships are valid A few or no key actants identified through crosslinks
Alliances (dispositifs)	Alliances clearly shown by highlighting many actants Clear messages outline the goals of the alliances	Alliances shown by highlighting some actants General messages outline the goals of the alliances	Alliances are vaguely shown or not at all There are no messages outlining the goals of the alliances
Placed "me" within the map	Students place themselves in the map Students illustrate connections of themselves with other actants	Students place themselves in the map without illustrating connections with other actants	Students didn't place themselves in the map

Finally, we assigned two points for every criterion that was fulfilled as exceeding standard; one point for each criterion that adequately meets standard; and no points for criteria that were below standard. accordingly, we classified as maps that "exceed standard" the maps that scored ten to eight points; "adequately meet standard" the maps that scored seven to five points; and as "below standard" the maps that got less than four points. According to the classification based on above criteria (Table 2), there are three ANT maps that are categorised as "exceeding standard"; three that "adequately meet standard"; and two that are "below standard" (Table 3).

Table 3. Categorisation of students' ANT maps according to level

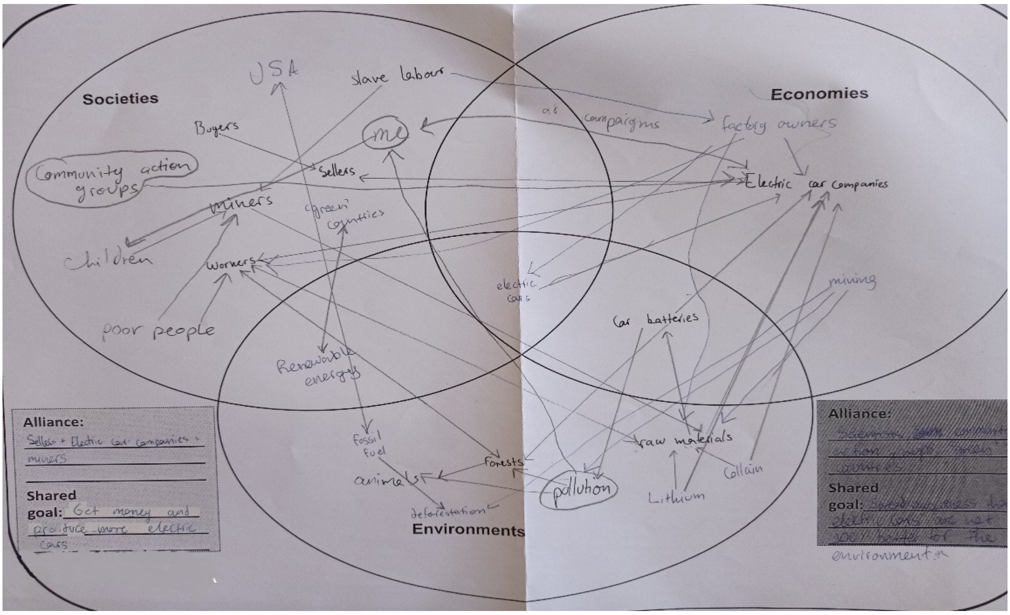
Students' names / topic of research	Points scored	Level of ANT map
Stathis and Ali / Electric cars	Ten (10)	exceeds standard
Thomas and Carol / Electric cars	Ten (10)	exceeds standard
Peter and Patricia / Smoking	Eight (8)	exceeds standard
Kiril and Alice / Global warming and extreme weather events	Six (6)	adequately meets standard
Allen and Nora / Electric cars	Five (5)	adequately meets standard
Helen and Fotis / Global warming and extreme weather events	Five (5)	adequately meets standard
Ioanna and Taahir / Electric cars	Three (3)	below standard
Willow and Kali / Global warming and extreme weather events	One (1)	below standard

Below you can find samples of students' ANT maps according to each level (Fig 1, 2 and 3). To answer our second research question -looking into how designing ANT maps promotes the understanding of sustainability issues- we will describe of the main features of the ANT maps complimented with students' reflections on the process of drawing them. These reflections convey, to some extent, students' knowledges about the relationships between actants in the frame of sustainability issues. For the sake of comparison, all three ANT maps link to the same topic (i.e. electric cars).

Exceeding Standard

An example of an ANT map that exceed standard is the one made by Stathis and Ali. It has a weblike structure without gaps, students have identified many human actants (i.e. buyers, miners, children), as well as many non-human actants (i.e. fossil fuel, animals, forests,) and some symbolic actants (i.e. 'green countries', advertisement campaigns). These are linked with many arrows, using some concepts such as "slave labour", "mining", "pollution", "deforestation" to describe their functions. Furthermore, students identified two alliances: one that includes the sellers, electric car companies and miners, with a shared goal to *"get money and produce more electric cars"* and one that consists of scientists, community action groups, green countries with the goal to *"spread awareness that electric cars are not 100% better for the environment"*. Students have placed themselves within the sphere of the society, illustrating with arrows links with other actants.

Figure 1. Sample of a network map that exceeds standard.



When Stathis reflected on his project work, he mentioned that he utilised his group's ANT map as a preliminary tool to link concepts and organize information about electric cars. For example, he said that:

> in the map, I could see (the arrows) when I was writing the final project so I could link them better" (notes taken from teacher's diary, May 2022)

Furthermore, Stathis seems to have found the triple Venn diagram framework helpful in clarifying the meaning of the dimensions of sustainability. For example, he mentioned:

> I thought (about) what the categories (dimensions of sustainability) could have in them and how it (each category) links with one another… (notes taken from teacher's diary, May 2022)

Also, Ali found the Venn diagram helpful, particularly as a part of the first cycle of activities:

> I could tell the differences between the areas which helped see the different groups before moving on to the topic we were actually doing

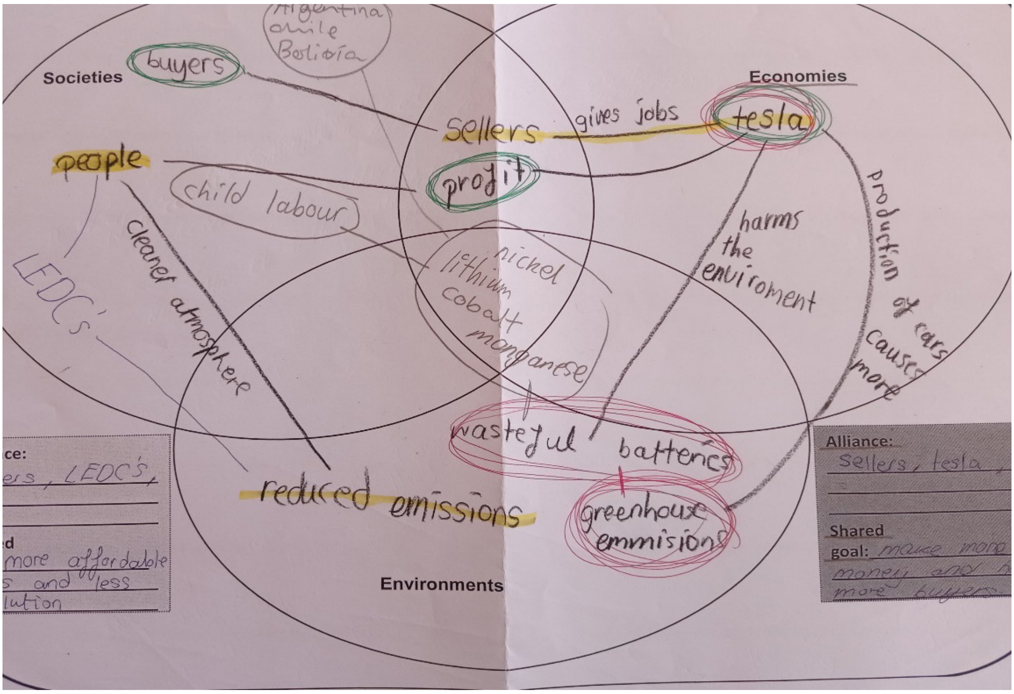
(notes taken from teacher's diary, May 2022)

From the above, there is evidence to suggest that ANT maps seem to have offered students a "snapshot" of the multiple interactions between actants. Also, the triple Venn diagram seem to have visualised the interactions between the fields of sustainability, which the students found useful.

Adequately Meets Standard

Adequately meets standard has been created by Allen and Nora. It is a generally well-designed map with a weblike structure, however there are seem to be some gaps between overlapping areas. Students have identified some human actants (i.e. people, sellers, buyers, children), some non-human actants (e.g. lithium, cobalt, atmosphere) and some semiotic actants (i.e. the name of company Tesla) which are linked with some lines. Students identified two alliances with messages: one that includes buyers and LEDCs with a shared goal to *"*(have) *more affordable cars and less pollution"* and one that consists of sellers and Tesla with the goal to *"make more money and have more buyers"*. Students haven't placed themselves within the map.

Fig. 2. Sample of a network map that adequately meets standards



When Nora was asked to reflect on the fact that there seem to be some gaps, she commented that she found it partly helpful and that she also struggled:

> The mind map helped us understand how each part (dimension of sustainability) is affected by electric cars… but we couldn't connect very

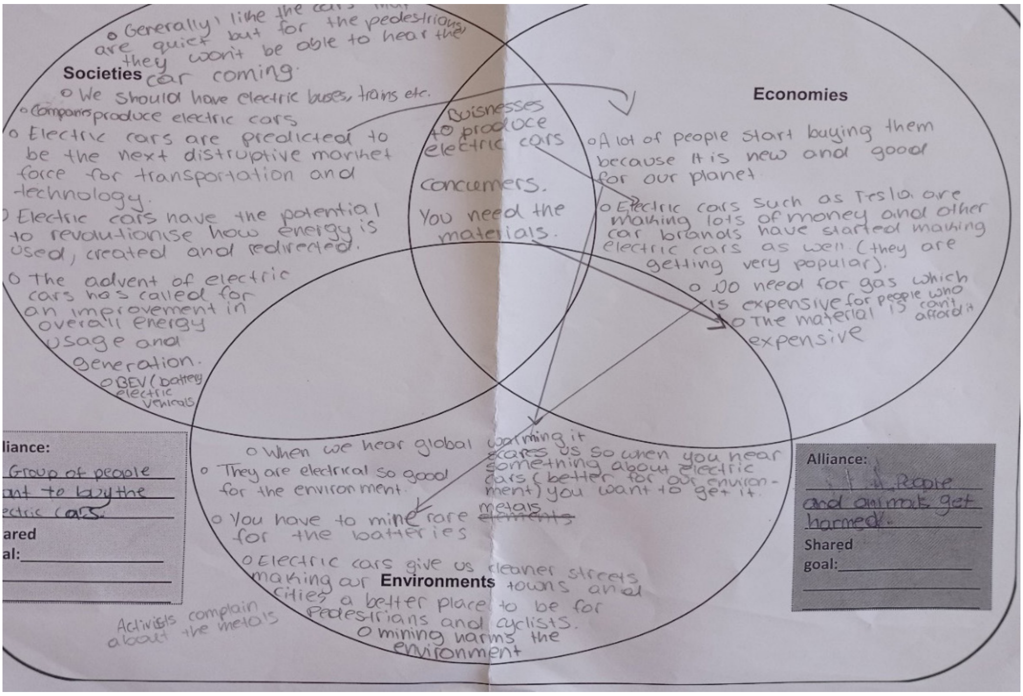
well economy and environment; we couldn't think of any more (actants that belong to both fields) (notes taken from teacher's diary, December 2021)

What is highlighted is the importance of further scaffolding relevant activities and preparing students for such higher order thinking. This was exemplified by Nora's reply, when asked if she had any suggestions about improving this type of activities. she suggested using a card game and categorising actants in a table before placing them in a map.

Below Standard

Finally, Taahir and Ioanna constructed a map that is classified as below standard. Students have identified a few general actants and processes (e.g. people, activists, pedestrians, cyclists, electric cars, batteries, materials, mining, metals, global warming) however this took the form of sentences rather than words and arrows, thus the relationships between actants is unclear. Furthermore, there are clear gaps on the overlapping areas. Students identified two vague alliances/ messages and didn't place themselves within the map.

Figure 3. Sample of a network map that is classified as below standard



When reflecting Taahir admitted that he struggled to visualise how the dimensions of sustainability overlap:

I was confused with the coverings between the fields, it was easier to give the basics and to see the differences between the fields. However, if

> I had time, I would build more connections (notes taken from teacher's diary, May 2022)

Also, at some point he commented that in general "he doesn't like overlaps", which is indicative of the way that such higher order thinking was challenging to him. On the other hand, his group mate Ioanna, said that she found that the Venn diagrams provided structure for her. From the above there is more evidence to suggest that students needed further support, especially, in terms of describing actants that have multiple roles in terms of the fields of sustainability.

Conclusion

In summary, we drew from concept map evaluation to design an evaluation rubric suitable for the ANT maps, which we have utilised in the frame of sustainability. The rubric is of our own design and has been made considering the principles of ANT maps in the frame of science education (Bencze and Krstovic, 2017, p. 176). In doing so, we prioritised the importance of drawing a weblike structure map, which would show complications consisting of a mixture of hierarchies. Furthermore, we gave merit to maps that contain a substantial number and a wide variety of actants (human; nonhuman; symbolic), as well as a substantial number of arrows demonstrating valid relationships. Finally, we considered whether students identified alliances and expressed clearly their common messages, in addition to whether they placed themselves in the map illustrating connections with other actants. We think that the field of evaluating ANT maps in education is a prominent field for scholarly development and other approaches, perhaps combining qualitative and quantitative data might also be effective.

From our research, there is evidence to suggest that our triple Venn diagram ANT maps seem to have facilitated students understanding of sustainability issues by scaffolding the description of interactions between actants and visualising how this occurs in the frame of the fields of sustainability. We consider this to be a useful first step for year 8 students, before they would be able to explore further and, even, question the distinctions between the fields themselves. However, students were also challenged, particularly by identifying alliances and describing actants that function in multiple fields, which highlights the need for further scaffolding. A limitation that we acknowledge in our work, is that we have presented only the end result of ANT maps and not the process through which they were designed. Finally, we think that the question of how ANT - and other concept - maps should be structured to best illustrate sustainability remains open for further research.

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Game-Based Learning in Environmental and Sustainability Education

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Game-based learning (GBL) is a didactic approach which fully integrates game characteristics with instructional content. It can provide a rich learning context to help learners construct higher-level knowledge and create immersive and engaging environments. It stimulates cognitive and emotional involvements, which are critical in deep learning. Games can play an especially prominent role in the university context, where they are used to vehiculate content knowledge in many different disciplines by promoting cognitive skills and competencies such as communication, collaboration, or problem-solving. However, lack of integration between gaming and teaching and a poor balance between enjoyment and education could undermine the efficacy of GBL in higher education. In this paper we show a preliminary case study, where the game "YouTopia – the ecosystem valley", a board game on ecosystems functioning, was implemented involving 24 students of the Master's degree course in Primary Education at the Free University of Bolzano – Bozen (Italy). This case study was implemented to understand how students of Educational Sciences perceive a board game as teaching tool for acquiring knowledge about ecosystem functioning, especially considering their limited background in ecology. Students played the boardgame and were then asked to fill out a short questionnaire, to elicit their perception regarding the playability, engagement, didactic value, and general appreciation of the boardgame. According to the questionnaire's results, the majority of students enjoyed the experience and were stimulated in boosting skills such as critical thinking, argumentation skills, and problem-solving. One-third of the students, however, did not perceive them to have acquired new knowledge or to have modified their beliefs. The efficacy of the proposed approach as a first hint to activate students in ecology issues is also discussed. The preliminary results are encouraging for further on-field tests and the development of other GBL units focused on other scientific topics.

Keywords: Game-based learning, ecosystem functioning, higher education.

Introduction

Eminent psychologists and educational researchers such as Montessori and Piaget have recognized the value of playing for the development of children and students for hundreds of years (Murray, 2018). Vygotsky (1987) described games as providing opportunities for children to experience scenarios they are not yet able to live through in real life. Thus, the importance of games for one's development has led to the inclusion of game-based settings for learning purposes (Kim et al., 2018). Game-based learning (GBL) is defined as the use of games as a main lesson or as enhancement of a lesson while keeping learning as the main desired outcome (Denham et al., 2016) aiming at facilitating knowledge learning and competence development or practice. This didactic approach fully integrates game characteristics with instructional contents. It can provide an interesting and stimulating learning context to foster students in acquiring and deepening knowledge, by creating immersive and engaging environments thus stimulating cognitive and emotional involvements which are critical in the learning process (Cheng et al., 2015).

The relevance of GBL in scientific education is recognized (Bakker et al., 2016) because it can provide a rich learning context to help learners construct higher-level knowledge through ambiguous and challenging trial-and-error and creating immersive and engaging environments. It also stimulates cognitive and emotional involvements which are critical in deeply learning STEM disciplines (Garris et al., 2002). Additionally, educational games are also receiving increased attention within the field of sustainability education (Sandbrook et al., 2015) both at school and in not formal educational context. Furthermore, GBL is increasingly becoming popular as a pedagogical tool to impart new skill sets to learners, which are popularly termed as the "new age 21st-century competencies" (Janakiraman et al., 2018), and to support Environmental and Sustainability Education (ESE).

Games can play an especially prominent role in the university context, where they are used to vehiculate content knowledge in many different disciplines by promoting cognitive skills and competencies such as communication, collaboration, or problem-solving. Despite the acceptance of educational games and GBL, there is little consensus about whether they enhance academic performance (Bai et al., 2020). Lack of integration between gaming and teaching and a poor balance between enjoyment and education are important shortcomings of educational games.

This paper describes how the board game *YouTopia – the ecosystem valley*, a cooperative board game focused on ecology and ecosystem functioning, has been implemented in a higher education context involving students of the Didactics of Biology class, within the Master's degree course in Primary Education.

Research Objective and Specific Questions

The main research objective of this case study is to understand how students of Primary Education perceive the use of a board game as teaching tool to transfer knowledge about ecosystem functioning and other related topics. The main research questions are:

1. How do university students of Primary Education perceive the use of board games as teaching tool?
2. Which scientific concepts do the students explicitly recognise?
3. What skills conveyed by the boardgame are explicitly recognised by the students?

The above-mentioned questions originate from the need to test the introduction of new didactic approaches within university education and especially in science education classes. Specifically, they stem from the idea that future teachers shall learn not only scientific concepts but also teaching approaches they can implement in their future classes at primary school.

Materials and Methods

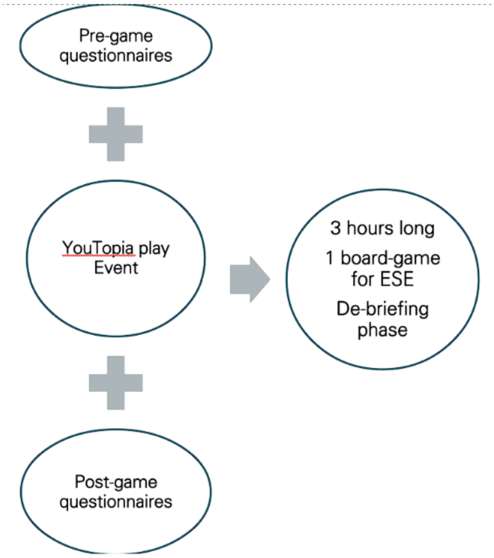
Recruitment and Participants

The empirical study took place between October and December 2022. The participants to the empirical study were voluntarily recruited from Didactics of Biology class of the master's degree course in Primary Education at the Free University of Bolzano-Bozen (Italy). Students received information about the study during a lecture, where they were introduced to the research project's purpose and methodology. They were informed that they would have received an invitation for filling out a voluntary post-gameplay questionnaire about their experiences once the gameplay sessions were over. Once the recruitment procedure was finished, a total of 24 individuals agreed to be part of the on-field game session and to receive the post-gameplay questionnaire. The age range of the respondents varied between 22 to 25 years; most of them were female and around 10% of participants were already working in the field of education and childcare.

Instruments and Experimental Procedure

A specific GBL unit was designed to introduce ecosystem-related concepts and to test how to implement GBL in higher education (Figure 1).

Figure 1: Structure of the GBL activity implemented with students of Didactic of Biology class in the academic year 2022-2023.



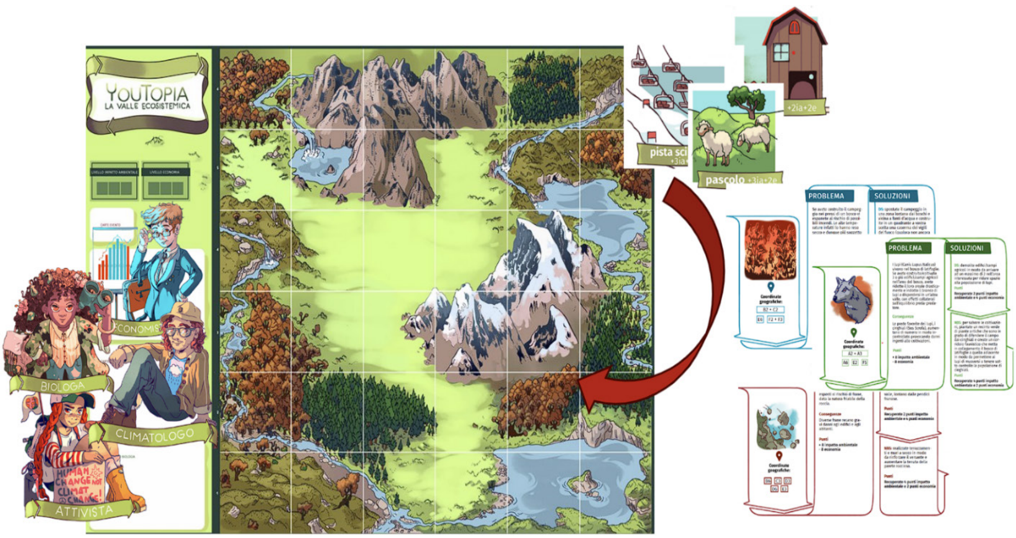
The on-field test consisted of three different activities:

- Introduction of the activity and pre-game questionnaire submission.
- GBL unit in which students tested the selected board game playing the game and discussing about ecology concepts during the de-briefing time (post-game discussion).
- Post–game questionnaire to receive feedback about the game experience in terms of perceived new knowledge acquired, engagement, and efficacy of the game.

Pre- and post-game questionnaires were developed by combining open-ended questions. The pre-game questionnaires aimed at testing ecology pre-knowledge and closed questions to evaluate the student's initial perception of games and how much experience they had in playing board games. The post-game questionnaire was developed by modifying the MEEGA+ model (Petri et al., 2016) to know how the game was perceived by the students in terms of usability and play experience. Additionally, some extra open-ended questions were introduced at the end of the didactic experience to better understand how the GBL in secondary education is perceived by the students and to

The selected boardgame is for the on-field test is "YouTopia – the ecosystem valley" (Figure 2). It is a boardgame developed to foster ecology, ecosystem functioning and knowledge in the framework of ESE in young people in formal and non-formal contexts. *YouTopia* is a cooperative boardgame for six players or groups of players to learn how an ecosystem works, by finding trade-offs in the management of human activities and natural and seminatural ecosystems, also considering environmental and societal changes. Each character has a different role (major, economist, geologist, activist, biologist, and climatologist). Characters must build up cooperatively a new settlement in a hypothetical alpine valley, considering on one side human needs for services and on the other side the environmental impacts these services produce. Each human action has two types of impact: an impact on the economy and an impact on the ecosystem. Each of the impacts is assigned a different score. Adverse events (geological events, extreme weather events or biodiversity losses) happen randomly during the game rounds and can lead to unfavourable consequences for the decisions made by each character. All players win if, after the three rounds and the occurrence of all the changes the final score in environmental impact the score in economy benefits is maintained within a specific range.

Figure 2. Game elements of the *YouTopia – the ecosystem valley* board game.

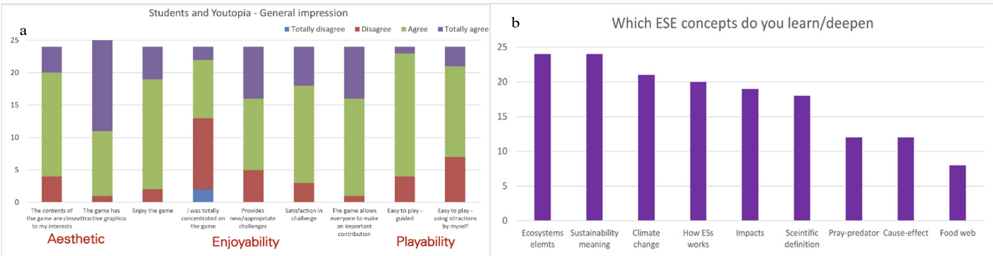


Results and Discussion

From post-game questionnaires of this case study, emerged that almost the total of students appreciated the board game *YouTopia – the ecosystem valley* considering three main aspects: aesthetic of game elements, playability and enjoyability of the game experience (Figure 3a). About the YouTopia boardgame, students highlighted as positive aspects the playability and the clear graphical aspects to introduce them in the understanding of ecosystem functioning. Students also enjoyed the experience of introducing a boardgame as part of the Didactics of Biology class, suggesting that GBL could be effectively integrated as an educational tool also at higher education level. Playing the game turned out to be helpful in deepening the concept of "ecosystem", and in learning some key topics such as "interrelation", "trophic networks" and "food-web" (Figure 3b).

However, one third of the respondents did not perceive to have acquired new knowledge or to have modified their beliefs after having played the boardgame. This might suggest that the boardgame alone is not sufficient to convey highly specific content, but it rather helps introduce the scientific concepts.

Figure 3: Student perception of the YouTopia game experience (a) and perception of ecology contents learned or deepen playing the game (b).

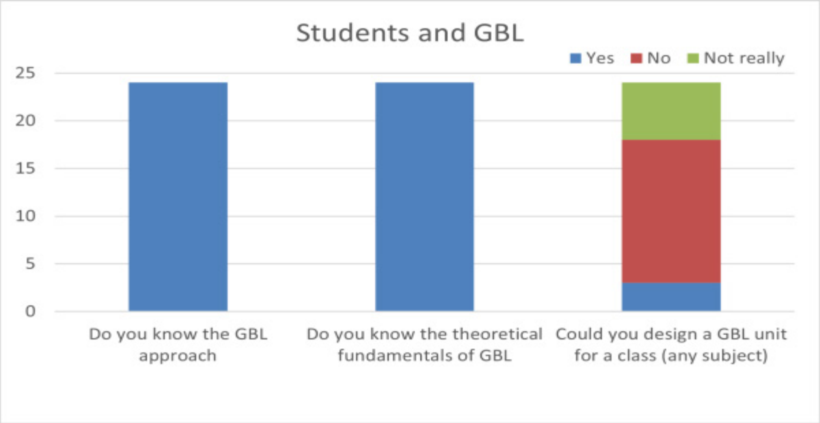


Most of the students proposed some changes to adapt the game for primary school pupils. It also emerged that using the boardgame helps them apply critical thinking, argumentation, collaboration, and problem-solving skills in reasoning about ecosystems and sustainability.

In interpreting the preliminary outcomes, we shall also consider that part of the scientific concepts was repeated also during the post-game discussion, using clear definitions, and taking the examples illustrated in the boardgame. The fact that some students did not perceive to have acquired new knowledge might suggest that the boardgame enjoyability can have a positive effect on the students' engagement, but it could limit their attitude in acquiring highly specific concepts.

Finally, we find interesting that post-game questionnaire highlighted that that students were not fully aware of the GBL approach (Figure 4).

Figure 4. Primary education students and GBL perception of theoretical knowledge and practical attitude in a future perspective.



From the results it emerged that students of Primary Education had no clear understanding of the GBL approach in science education before the YouTopia lab. Checking questionnaire and debriefing results it seems that they know the theoretical principles and educational potential of games, however, when they come into practice approach students seem to be confident and ready to design and implement GBL in primary classes.

Future Perspective

Considering the positive response to the GBL in secondary education is encouraging for a change of paradigm in secondary education. Further tests are planned to better understand how to effectively adopt games in science and ESE at secondary level. It seems that for ecology and more for sustainability education, games have a potential to become effective to deepen knowledge and to practice them in a realistic context. Additionally, for future teachers seems to be relevant to practice innovative approaches such as GBL to be able to transfer these approaches in their future as primary school teachers. However, some elements should be considered; games are generally good to facilitate how theory of ecology come into practice, but solid scientific background is needed such as a strong debriefing moment is needed to fix knowledge acquired.

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Binding the Sustainable Development and the Curriculum: The Effect of a Training for Pre-Service Physics Teachers

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This study aims to examine the effect of sustainable development (SD) training on pre-service physics teachers' binding SD and secondary education physics curriculum. Eight trainers carried out the 5-day online training with the support of TÜBİTAK 2237-A Scientific Activities Support Program. 26 physics teacher candidates participated, 19 of whom were included in this research sample. The training covered sustainable development goals, relevant applications, and teaching methods to promote sustainable development. At the beginning and at the end of the training, physics teacher candidates were asked to bind the physics topics with sustainable development. The data was analyzed using the grades and units given in the curriculum. The results showed a significant increase in the number of units bound to sustainable development for almost all grades. After the training, pre-service physics teachers displayed a more comprehensive understanding of sustainable development and made more connections between the physics units and sustainable development. The findings also indicated that the training positively influenced binding sustainable development into the physics curriculum. Furthermore, units including energy-related concepts have increased the binding of the physics curriculum with sustainable development.

Keywords: Sustainable development, physics education, physics curriculum.

Introduction

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 and consist of 17 interconnected core objectives (United Nations Development Programme [UNDP], 2016). To achieve these goals, educating societies on relevant issues is crucial. Thus, Education for Sustainable Development (ESD) has emerged as an essential concept. In the early 2000s, although no nation meaningfully reflected the philosophy of SD in their education systems (Yapıcı, 2003), previous studies show that education plays a fundamental role in achieving SD (Amusa, 2015; Nasri et al., 2020). ESD includes education and training activities that aim to change individuals' attitudes, consumption habits, and behaviors, requiring systematic thinking, joint decision-making, and implementation for future generations (Bulut & Çakmak, 2018). ESD is the process of acquiring knowledge, skills, and values necessary to ensure that our world becomes safer, healthier, and more prosperous by changing the perspectives of individuals, groups, communities, institutions, and countries in favor of SD and striving for people to live sustainably, increase their contribution to a democratic society, and support sustainable behavior (The United Nations Economic Commission for Europe [UNECE], 2003).

Özerdinç et al. (2022) have studied 34 theses and 11 articles on SD in education between 2010 and 2020. They found that studies mainly focused on determining SD awareness and opinions about SD. In another study conducted on ESD, Aytar and Özsevgeç (2019) revealed that interdisciplinary ESD education developed with 199 seventh-grade students positively improved their conceptual understanding of biodiversity, soil pollution, hunger, renewable-non-renewable energy resources, and recycling. Increasing individuals' awareness of SD will make it easier to achieve educational goals (Brause & Wood, 1993). Thus, it is not wrong to assume that teaching lessons for SD purposes will increase SD awareness, just as high SD awareness positively affects course success.

According to Uitto and Saloranta (2017), ESD should be included in the school curriculum to integrate SD principles, values, and practices into education. They researched the perceptions of secondary school branch teachers, who are sustainability educators, regarding ESD competencies and the different dimensions of ESD (ecological, economic, social, welfare, cultural) in their teaching. The study found that only mathematics, physics, and chemistry teachers explicitly focused on education for ESD but only focused on the environmental dimension of sustainability. Therefore, teachers can only include SD in the education process in a narrow scope. In another study, Gökmen (2014) discovered that although pre-service teachers in physics, chemistry, and biology showed high attitudes toward education for SD and their corresponding scores for SD and development indicators were high, their SD success scores were low. The study also revealed that 33% of pre-service teachers had no information about SD, and 41% did not have any information about ESD. This research suggests that teachers' failure to incorporate sustainable development-related content into the teaching process dates back to before they started their professional lives.

Unsurprisingly, the study samples conducted in Türkiye on SD focus on pre-service teachers and teachers (Özerdinç et al., 2022). Education should consider SD a crucial and ongoing issue rather than a passing trend. For this reason, our pre-service teachers who will educate future individuals should act with this awareness and consider SD objectives as one of their teaching purposes. Although some studies provide meaningful learning through education for SD and global citizenship, studies with this purpose must be increased (O'Flaherty & Liddy, 2018).

In order to promote sustainability in education, it is essential to inform pre-service teachers about SD and train them on how to incorporate it into their lesson planning (Sustainable Development Goals Evaluation Report, 2019). In line with this, an educational event called "Physics Education for Sustainable Development" addressed SD in physics education for pre-service teachers. Türkiye's Scientific and Technical Research Council (TÜBİTAK-2237A) supported this online training under the ID: TBTK-0017-6614. This research assesses the effect of sustainable development (SD) training on physics pre-service physics teachers' binding SD and Secondary School Physics Course Curriculum based on grades (Ministry of Education [MoNE], 2018).

Method

This study has employed a one-group pretest-posttest pre-experimental design, which involves only one group tested before and after an intervention. This type of study does not involve any randomization. The data is collected quantitatively, and the results are interpreted using descriptive analysis techniques.

Participants

The trainers have been chosen as participants in the training program based on purposeful and voluntary participation. There are two prerequisites to participate in the training, which include (i) being a student in the physics education department (being a pre-service teacher) and (ii) having completed at least the introductory courses by being in the third year of education. There are eight universities in Türkiye which offer the Physics Teaching Program to students. The announcement for the training program was sent through the Internet to all eight universities in Türkiye that offer physics education courses. The physics teacher candidates were informed about the study's content and their approval was obtained during the application process. Therefore, the participants participated in the study voluntarily. Table 1 presents some demographic information of the participants.

Table 1. Demographic information of the participants

Participants	Gender	University	Year	Participants	Gender	University	Year
P1	M	Gazi University	5	P11	F	Gazi University	5
P2	M	Hacettepe University	4	P12	M	Hacettepe University	3
P3	M	Hacettepe University	3	P13	F	Boğaziçi University	4
P4	F	Boğaziçi University	4	P14	F	Marmara University	5
P5	F	Marmara University	4	P15	F	Gazi University	5
P6	F	Boğaziçi University	4	P16	F	Marmara University	4
P7	F	Gazi University	5	P17	F	Middle East Technical University	3
P8	F	Necmettin Erbakan University	4	P18	F	Gazi University	4
P9	M	Marmara University	4	P19	F	Middle East Technical University	4
P10	M	Gazi University	4				

Table 1 shows that the participants of this training program are from six of eight universities in Türkiye which offer the Physics Teaching Program to students. A total of 19 pre-service physics teachers participated, of which six were male and 13 were female. Three of them are juniors, while 11 are seniors. Additionally, five participants are currently in their fifth year of education.

Training

The training program titled "Physics Education for Sustainable Development" has been funded by TÜBİTAK and consists of 39 lectures, each of 30 minutes duration, for five days. The training was conducted online, with eight (4+4) lectures given daily in two separate sessions and seven (4+3) on the last day. The lectures were delivered by eight experienced physics educators, all of whom hold doctoral degrees. The training program covers a wide range of topics related to physics education and its relationship with sustainable development:

On the first day, the program started with a meeting and briefing session followed by lectures on sustainable development, The Relationship between Sustainable Development and Physics, Applications of Physics Examples for Sustainable Development Goals, and Sustainable Development in Physics Education with Creative Drama.

On the second day it was focused on Teaching for Conceptual Change: Physics Education in the Context of Sustainable Development with the Learning Circle Model and Sustainable Development in Physics Education with a Context-based

Approach.

On the third day, the subjects were Sustainable Development with Digital game-based Physics Education and Physics Education in Sustainable Development with Arduino.

On the fourth day, participants attended Physics Education in Sustainable Development with Problem-based Learning and Physics Education in Sustainable Development with Argumentation-Based Learning lectures.

Finally, on the fifth day, the subject was Physics education of visually impaired students for sustainable development, and participants attended an evaluation meeting.

Measuring Tools and Analysis

Pre-service physics teachers were surveyed before and after training to identify which physics units were related to sustainable development. At the beginning of the training, a pre-test was administered to participants who met the training prerequisites. At the end of the training, a post-test was administered to participants to evaluate the program's effectiveness. Data collected from 19 participants who took both tests was analyzed. In test, participants were asked to mark the physics units in the Secondary Education Physics Curriculum (MoNE, 2018) that were binding to sustainable development. The physics curriculum is prepared for Grades 9, 10, 11, and 12 and includes six, four, two, and six units, respectively. The test was administered online. We processed the data in two stages. First, we determined the frequencies of the units marked by the pre-service physics teachers to reveal the changes in the comprehension of each pre-service teacher who participated in the training. This allowed us to see individual changes. Then, we discussed the findings in the context of the units, and we were able to determine the effect of the training in binding the SD with the units.

Results

The frequencies of pre-service physics teachers according to physics units they bound with sustainable development based on grade level in the pre- and post-test were given in figures 1 and 2 respectively.

Figure 1. Frequency of pre-service physics teachers according to physics units they bound with SD based on grade level in the pre-test

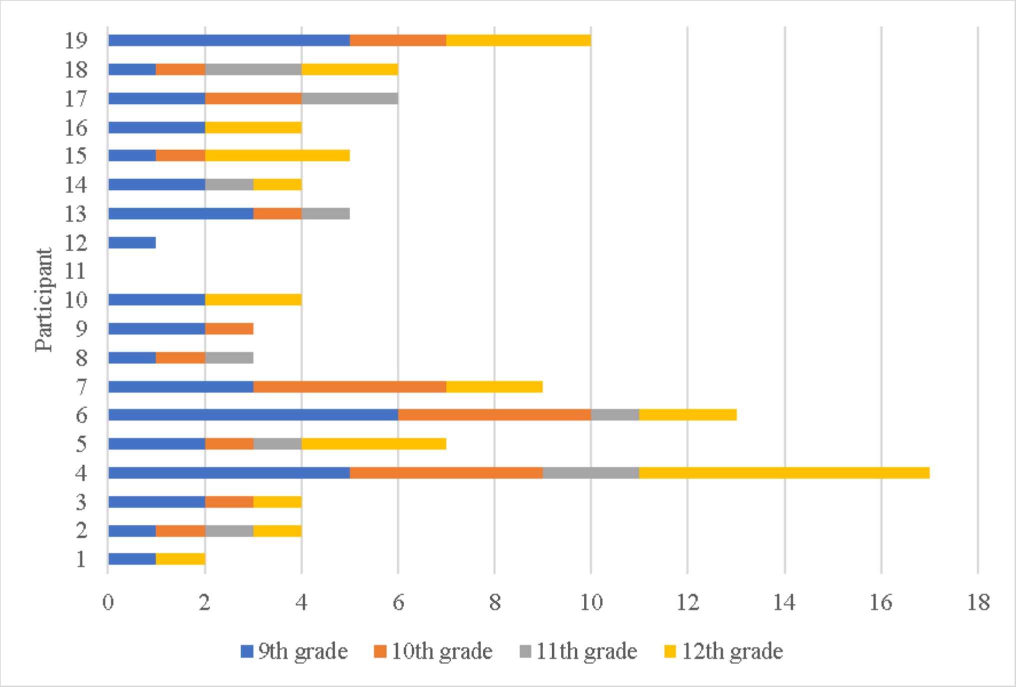


Figure 1 indicates that in the pre-test, 18 of the 19 pre-service physics teachers bound the ninth grade with SD, 13 with the 10th, nine with the 11th, and 13 with the 12th. Figure 2 shows that all pre-service physics teachers bound the ninth and 10th grade units with SD, 15 bound the 11th grade, and 14 bound the 12th grade. Though most pre-service physics teachers could bind the ninth-grade units with SD before the training, fewer pre-service physics teachers could bind other grade levels. After the training, there was a significant increase in the number of pre-service physics teachers who could make binds, particularly at the 10th and 11th-grade levels.

Figure 2. Frequency of pre-service physics teachers according to physics units they bound with SD based on grade level in the post-test

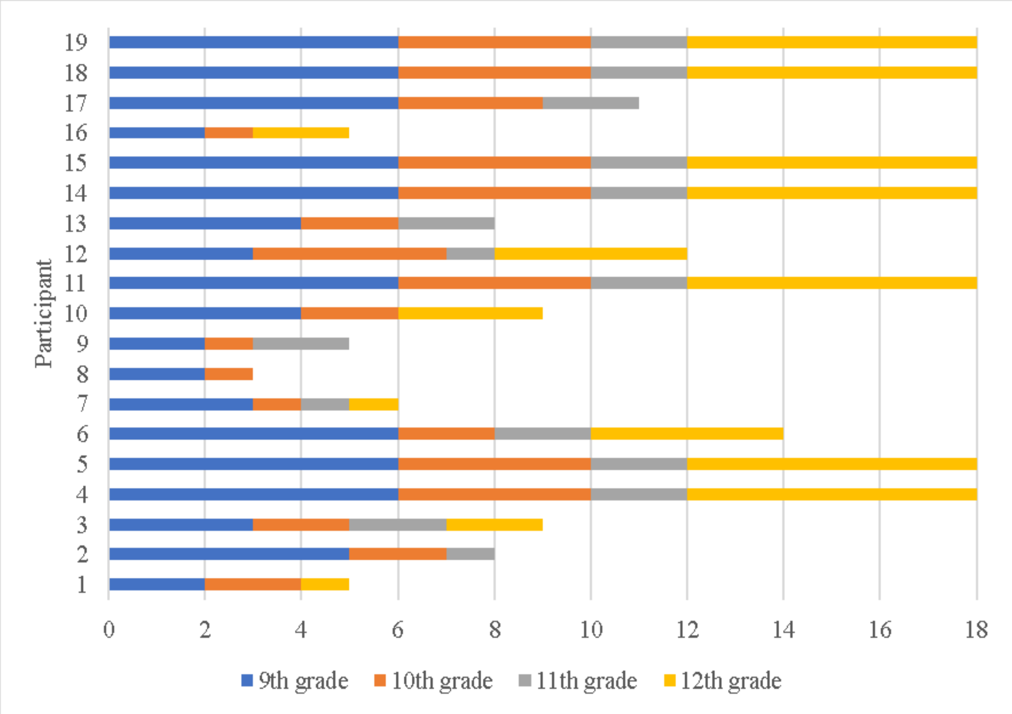
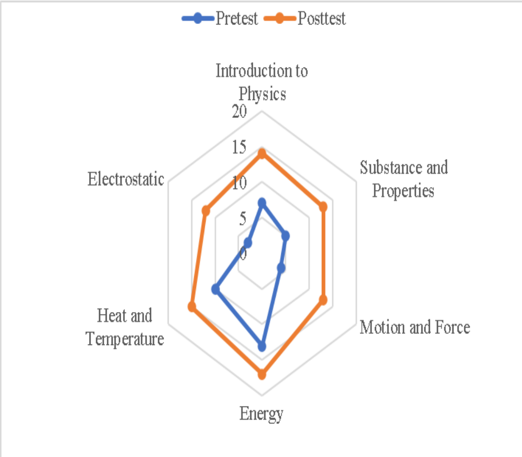


Figure 1 shows that one pre-service physics teacher did not make any bindings at any grade level in the pre-test (P11). Most other pre-service physics teachers did not make bindings at specific grade levels (P1, P3, P7, P8, P9, P11, P12, P13, P14, P15, P16, P17, and P19). However, five pre-service physics teachers made bindings at all grade levels during the pre-test (P2, P4, P5, P6, P18). Figure 2 shows that P11 made bindings with all units at each grade level during the post-test. Moreover, six more pre-service physics teachers could make bindings with all units at each grade level (P4, P5, P14, P15, P18, and P19). Additionally, P3, P6, P7, and P12 could make bindings with various units at all grade levels. The number of units bound with SD increased for all participants except P7 and P8.

While before the training, approximately 21% of the participants associated more than 50% of the units with sustainable development, this rate increased to approximately 58% after the training. It is revealed that the training enabled most pre-service physics teachers to think about sustainable development more broadly, except for P7 and P8.

Figure 3 shows the frequency of pre-service physics teachers who were able to make bindings with SD in both the pre-test and post-test according to each unit.



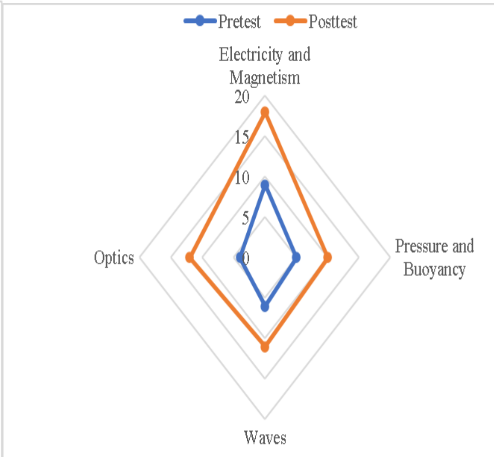
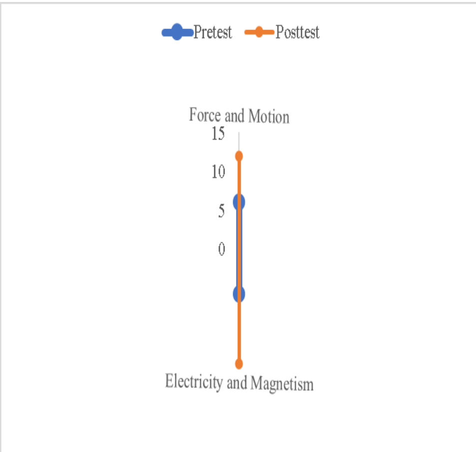


Figure 3a. 9th grade

Figure 3b. 10th grade



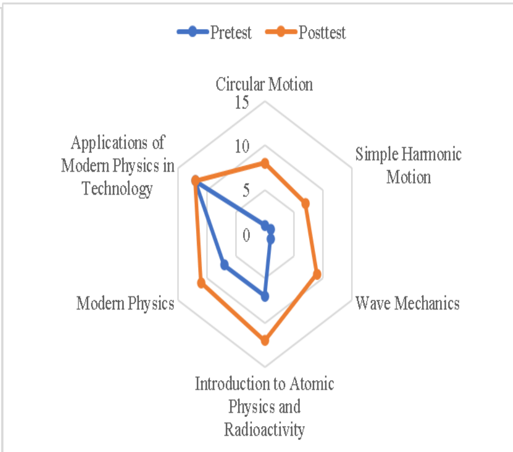


Figure 3c. 11th grade

Figure 3d. 12th grade

Based on Figure 3, the number of bindings for only one unit in the post-test remained the same as in the pre-test. This unit is the Applications of Modern Physics in Technology. Out of the 18 units assessed across all grade levels, the highest increase was observed in Electrostatics and Force and motion for the ninth grade, Electricity and magnetism for the 10th and 11th grades, and Substance and properties for the ninth grade. Following these, the highest increase was observed in Optics and unit Wave Mechanics for the 10th and 12th grades, respectively. In addition, the smallest increase was observed in Energy and Modern Physics units for the ninth and 12th grades, respectively.

In the pre-test, pre-service physics teachers most frequently bound Energy and Heat and temperature units in the ninth grade and Applications of Modern Physics in Technology in the 12th grade. Following these, Electricity and Magnetism in the 10th grade was also commonly bound. In the post-test, pre-service physics teachers mostly bound Energy in the ninth grade, Electricity and magnetism in the 10th and 11th grades and Heat and temperature in the ninth grade. Three units in the 12th grade, Circular Motion, Simple Harmonic Motion, and Wave Mechanics, were bound by only one student in the pre-test, but in the post-test, almost half of the physics teacher bound these units.

Upon examining Figure 3, it becomes apparent that most of the changes in the graph for each class are in the direction of increase. However, while the pretest and post-test graphs in Figures 3b and 3c appear similar in the 10th and 11th grades, the appearances of the pretest and post-test graphs in the ninth and 12th grades differ. These are due to the higher rate of change in the Electrostatic and Force and motion units compared to other units and the absence of change in the Applications of Modern Physics in Technology unit.

Conclusion

The research findings indicate that the "Physics Education for Sustainable Development" training has increased the number of pre-service physics teachers who bound the Secondary School Physics Curriculum units with SD. Before the training, pre-service physics teachers mainly focused on binding the Energy, Heat and temperature, and Applications of Modern Physics in Technology units with SD. However, after the training, there was a rise in the number of pre-service physics teachers who believe that all units, except one, are related to SD. The only unit that did not see an increase is the Applications of Modern Physics in Technology unit, which most participants already saw as being bound to SD before the training.

The training positively impacted increasing the number of binds between the content of the units and SD. However, it greatly affected the Electrostatic, and Force and Motion units. This situation may have arisen from the examples provided by the trainers and the change in participants' perspectives on the subject.

The study found that most pre-service physics teachers bound the units covering Mechanical Energy, Heat, and Temperature with SD before and after the training. On the other hand, the increase in pre-service physics teachers who bound units covering Electrostatics, Electricity, and Magnetism with SD was highest in the post-test. These situations suggest that pre-service physics teachers show more binding to SD when energy-related concepts are included in the units.

Acknowledgement

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Climate Change Awareness Profiles of Japanese Primary School Children: A Pilot Study

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The present pilot study aimed to achieve two primary objectives: (1) to develop and validate a Japanese version of the Climate Change Awareness Scale, and (2) to classify primary school children from Hiroshima prefecture, Japan into groups based on their climate change awareness profiles using the scale. The sample of this study consisted of 181 primary school children from three schools. Results from the pilot testing revealed that the Japanese Climate Change Awareness Scale exhibited a high level of reliability and validity, and was composed of two factors: perception and action. A two-step clustering analysis was conducted to identify trends in the children's climate change awareness. The clustering analysis identified four distinct groups of children: active-reflective, active-impulsive, passive-apathetic, and passive-contemplative. These findings may inform future studies on the effective integration of climate change education into the primary school science curriculum, by developing lesson plans tailored to the specific needs of each group.

Keywords: Climate Change Awareness, Japanese Primary School Children, Cluster Analysis

Introduction

Background of the study

As we confront the escalating challenges of climate change, the role of Climate Change Education (CCE) in empowering younger generations becomes increasingly vital. Essential to the formal education system, CCE's integration, especially in primary school curricula, is critical, yet many countries in the Asia-Pacific face a significant gap in this area (UNESCO, 2021). For instance, Vanuatu's education system delays in-depth disaster and climate change learning until secondary education's end (Pierce & Hemstock, 2021), exemplifying global inconsistencies in CCE implementation. Similarly, Zhan et al. (2018) shed light on China's 'green gap' in environmental education, underscoring the reliance on traditional lecture-based methods. This oversight is particularly concerning given the essential socioemotional and cognitive development occurring during primary school years when children are increasingly able to grasp complex concepts like climate change. The integration of CCE into science curricula is therefore not just beneficial but necessary for nurturing a long-term understanding and proactive response to climate issues (Fujii, 2022). This necessity is echoed in longitudinal studies in Japan such as Miyashita et al. (2020), which demonstrate the persistence of knowledge and misconceptions about global warming acquired in early education. Moreover, research from the United States by Lawson et al. (2019) highlights the significant societal impact of CCE through child-to-parent intergenerational learning, where middle school students notably influence their parents' views on climate change.

Focus of the study

This study presented result of a pilot testing of a scale that was developed to measure climate change awareness among Japanese primary school children. Data from the pilot testing of the scale was also used in a cluster analysis to determines profile of the children based on their climate change awareness. Result of this study may serve as a foundation for the development of effective CCE curriculum to support primary school students' development of cognitive, socioemotional and behavioural profile towards climate action, by improving their climate change awareness. Specifically, this study addresses the following research questions (RQs):

- **RQ1:** *What is the result of reliability and validity analysis of Japanese version of a scale to measure climate change awareness among Japanese primary school children?*
- **RQ2:** *What is the result of cluster analysis to categorize a sample of Japanese primary school children based on their climate change awareness profile?*

RQ1 evaluates the scale's psychometric properties, specifically its reliability in assessing Japanese primary school children. Reliability analysis checks the scale's consistency over time, while validity analysis determines how accurately the scale measures climate change awareness. Both are crucial for drawing meaningful conclusions and developing appropriate educational strategies. RQ2 involves applying cluster analysis to the collected data. This statistical method groups individuals based on common characteristics, here, their climate change awareness. Identifying different awareness profiles is essential for tailoring educational strategies and CCE curricula to meet diverse student needs. Understanding these profiles allows for more effective, targeted educational interventions, enhancing CCE's overall impact in primary education.

Methods

Research Instrument

The development of the Climate Change Awareness Scale (CAS) was undertaken to measure the profile of Japanese primary school children. The CAS was created by adopting five factors from multiple studies: Knowledge (Taddicken et al., 2018), Concern (Hickman et al., 2021), Behaviour (Miyashita et. al., 2020), Attitude, and Action (Kuthe et al., 2019). The knowledge dimension was informed by the national primary school science curriculum in Japan. The initial draft of the CAS consisted of 15 Likert scale-type items. These items were developed through consultation with experts in climate change education, primary school education, and science education.

Data Collection

Prior to pilot testing, a small sample of primary school children participated to assess readability of the draft. The draft was then, administered to fifth and sixth grader from three primary schools in Hiroshima prefecture, Japan. The school was selected through non-probabilistic sampling on the basis of expert judgment and convenience. Consent was obtained from the schools on behalf of the participating students' parents and guardians. The removal of incomplete data resulted in a final sample of 181 of primary school children, comprising 103 fifth-graders and 78 sixth-graders.

Data Analysis

Prior to clustering analysis, a principal component analysis (PCA) with varimax rotation and Kaiser normalization was conducted, based on the final sample. Items in the initial draft with loadings lower than 0.4 or that loaded on multiple components were removed. Cronbach's alpha was then calculated to evaluate reliability of the draft. Then, using Schwarz's Bayesian Criterion (BIC) as the clustering criterion, a two-step cluster analysis was performed using IBM SPSS 29.

Results

Reliability and Validity Analysis

The PCA resulted in the elimination of four items from the scale, resulting in 11 items and a reduction of factors from five to two. The first factor, "Perception about Climate Change," includes seven items that represent knowledge, concern, and attitude. The second factor, "Action Towards Combating Climate Change," includes four items that represent behaviour and actions. Both factors were found to be reliable with Cronbach's alpha values of 0.839 and 0.865, respectively.

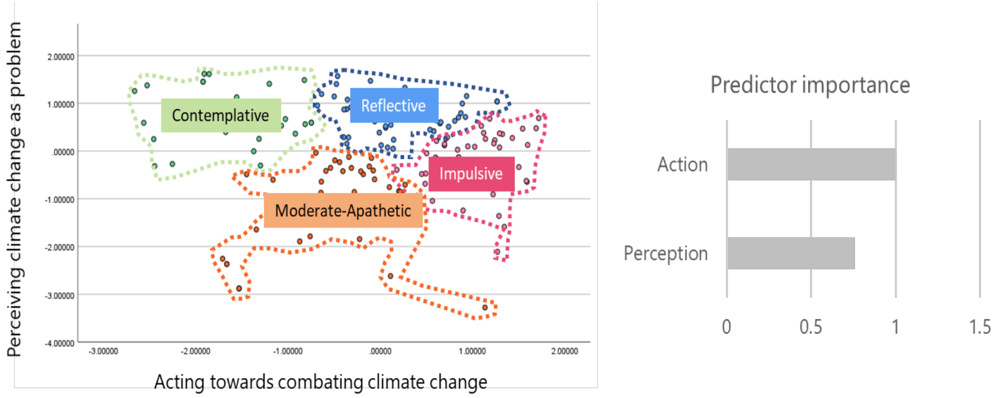
Table 1. Items in the final draft of CAS Questionnaire for Japanese Primary School Children

Item*	Factors	α
Perception about climate change (1 = no, 2 =somewhat no, 3=somewhat yes, 4=yes)		
1	I am interested in reducing carbon dioxide to stop climate change.	0.839 (good)
2	I think that carbon dioxide is making the temperature go up.	
3	I am worried about the climate change.	
4	I am worried that not enough is being done to stop climate change	
5	I think that using fossil fuels (like coal and oil) will make climate change continue.	
6	I think climate change is causing the ocean surface to rise.	
7	*I think that to stop climate change, countries need to work together.*	
Action toward combating climate change (1 = no, 2 =somewhat no, 3=somewhat yes, 4=yes)		
8	I often talk with my friends and family about how to stop climate change	0.865 (good)
9	I don't use too much electricity to stop climate change.	
10	I don't use too much water or hot water to stop climate change.	
11	I often tell my family and friends to do something to stop climate change.	

Cluster Analysis

A Two-Step Cluster Analysis was conducted to investigate the climate change awareness profile of primary school children. The results of the analysis revealed that action towards combating climate change (1.00) was a more significant predictor than perception about climate change (0.76) in determining the clusters of children. The cluster analysis also revealed that four distinct groups of primary school children emerged from the analysis, which we labelled as Contemplative (14.4%), Moderate-Apathetic (26%), Reflective (32%), Impulsive (27.6%) based on their response, as featured in Figure 1.

Figure 1. Cluster Analysis Result (N = 181).



Cluster 1	Cluster 2	Cluster 3	Cluster 4
Contemplative	Moderate-Apathetic	Reflective	Impulsive
14%	26%	32%	28%
Perception (0.72)	Action (-0.45)	Perception (.79)	Action (1.03)
Action (-1.59)	Perception (-1.14)	Action (.20)	Perception (-.22)

14

Discussion

Two Factors Constructing Climate Change Awareness

Perception about Climate Change

The first factor, “Perception about Climate Change,” emerged as a composite of three originally separate domains: knowledge, concern, and attitude. This factor, now integrating seven items, effectively captures both cognitive and affective dimensions of children’s understanding of climate change. It encompasses items that assess students’ factual knowledge about climate change, their emotional responses to the issue, and their overall attitudes towards its significance and impact. The inclusion of knowledge is crucial, as studies by Ferrari et. al. (2022), Masud et al. (2015), and Gunamantha & Dantes (2019) illustrate the direct impact of climate change knowledge on attitudes and abilities. Emotional responses, such as concern or anxiety, are also pivotal, as noted by Etkin & Ho (2007) in their discussion on risk perception. Additionally, this factor aligns with the environmental literacy model proposed by Bissinger & Bogner (2018), which links knowledge and attitude. Dijkstra & Goedhart (2012) also contribute to this understanding with their exploration of the relationship between science-related attitudes and climate change/environment-related attitudes. Overall, the “Perception” factor reflects a holistic approach to understanding children’s climate change perception, as it merges cognitive aspects, emotional responses, and the formative influence of educational interventions.

Action towards Combating Climate Change

The second factor, "Action towards Combating Climate Change," consists of four items and represents the practical dimension of the scale. It focuses on behaviours and tangible actions that children might take or advocate for in response to climate change. This factor crucially represents the shift from awareness and attitudes about climate change to concrete behaviours and actions in children. This transition is illuminated by various studies: Nguyen et al. (2018) applied the Theory of Reasoned Action to predict behaviour intentions among Vietnamese schoolchildren, establishing a significant correlation between awareness and intended climate actions. Trott & Weinberg (2020) further highlighted how CCE fosters deeper scientific understanding and active engagement among children, while Azul & Reis (2018) focused on participatory research and hands-on activities in enhancing decision-making skills for climate action. The influence of education extends to families as well, as noted by Lawson et al. (2019), who observed that children's climate education can indirectly heighten their parents' awareness and action. Hiramatsu et al. (2014) further support this by showing that environmental education programs can have "spillover effects" on entire family units. Additionally, Karpudewan and Mohd. Ali Khan (2019) underscores the role of values, beliefs, and personal norms in promoting climate-conserving behaviours among Malaysian primary school students, indicating that fostering these aspects is key in encouraging proactive environmental actions.

Four Clusters of Children based on Climate Change Awareness

Our research on Japanese children employed Principal Component Analysis (PCA) to emphasize two primary factors: perception and action. This approach differs significantly from that of Kuthe et al. (2019), who explored a broader set of variables (knowledge, behaviour, attitude, and concern) in their study of Austrian and German teenagers. Our methodology led to the creation of a novel classification system, categorizing the children into four distinct clusters according to their individual climate change awareness profiles. In the subsequent section, detailed in Table 2, we draw upon insights from various sources, notably Monroe et al. (2019), who examined effective strategies for CCE. This information is used to customize educational strategies to suit the specific needs of each identified cluster. The underlying assumption of our approach is that research focusing on older age groups can be crucial in enhancing strategies for primary education. This premise is supported by the idea, as argued by Miyashita (2020), that early learning experiences form a foundation for the knowledge and skills that are carried into adulthood.

Table 2. Characteristics of each group and proposed pedagogy based on literature review

Cluster	Description	Possible Cause	Proposed Pedagogy
1.Contemplative	Moderate score on the perception, but low score on the action	Lack of knowledge on effective actions, psychological barriers like eco-anxiety	Engaging in deliberative discussions, interactive sessions with experts, school/community projects
2.Moderate-Apathetic	Lowest score on both perception and action	Disconnect from environmental issues, lack of relevant information/ resources	Personally relevant information, active teaching methods like hands-on experiments, collaborative projects
3.Reflective	Highest score on the perception, but lower score on the action.	Strong awareness and sense of empowerment	Advanced discussions and activities, real-world scenarios, climate action projects
4.Impulsive	Highest score on action but very low score on perception.	Influenced by external factors like peer pressure, limited grasp of complexities	Education on complexities of climate change, role-playing or simulation games

Contemplative Cluster (14.4%): High understanding, low action

This cluster of children is characterized by their high awareness of climate change issues, yet they demonstrate a low inclination to take meaningful action. This distinct combination sets them apart from any group identified in Kuthe et al. (2019)'s study. Despite their high awareness, these children exhibit a thoughtful yet passive approach, recognizing the significance of climate change but hesitating in translating this understanding into concrete actions. The reasons for their inaction may be multifaceted. It could be due to a lack of knowledge about what effective actions to take in response to climate change. Alternatively, they might be experiencing a deficit in motivation, which prevents them from acting on their understanding of the issue. Benoit et al. (2021) suggest that psychological barriers, such as eco-anxiety, may prevent them from translating their understanding into action. Additionally, a lack of knowledge about effective actions to respond to climate change might contribute to their inactivity. Trott (2020) proposes that participatory methods in educational settings could empower these children, providing both knowledge and motivation to overcome these barriers. This cluster's high awareness yet low inclination to act can be addressed using Monroe et al.'s (2019) suggestion of engaging in deliberative discussions, which can help clarify misconceptions and promote a deeper understanding of effective climate actions. This approach could be complemented by interactive sessions where these children can directly engage with scientists or environmental experts, providing them with real-world insights and motivating them to translate their knowledge into action. Monroe et al. (2019) also emphasises the effectiveness of school or community projects, which could be particularly beneficial for this group by providing practical avenues for engagement and demonstrating the tangible impact of their actions.

Moderate-Apathetic Cluster (26%): Moderate understanding, minimal action

Children in this group are marked by both low levels of awareness and action regarding climate change. Their characteristics align somewhat with Kuthe et al. (2019)'s 'Disengaged' group, but with notable differences. The term 'Moderate-Apathetic' aptly captures their state – they have a middling or moderate level of awareness about climate change and simultaneously exhibit a lack of active response to the issue. This cluster's stance suggests not only a potential lack of access to relevant information or resources related to climate change but also a perception that climate change is not a matter directly relevant or significant to their daily lives. Their moderate awareness, combined with their inactivity, indicates a disconnect or a lack of engagement with environmental issues. Deisenrieder et al. (2020) note that participatory climate change education could bridge this action gap, indicating that enhanced educational approaches might engage these children more effectively. This group's stance suggests a disconnect or a lack of engagement with environmental issues, potentially due to a lack of access to relevant information or resources. For this group, Monroe et al. (2019) strategy of using personally relevant and meaningful information could be instrumental. By connecting climate change concepts to the children's own lives and local communities, educators can make the subject more relatable and urgent. Additionally, Monroe et al. (2019) advocate for active and engaging teaching methods, such as hands-on experiments or collaborative projects, which could stimulate interest and encourage participation among children who otherwise show little inclination towards climate change action.

Reflective Cluster (32%): High understanding - proactive action

This is the largest group in the study. The 'Reflective' children show a balanced blend of high perception of climate change and proactive action in response to it, similar to Kuthe et al. (2019)'s 'Concerned Activists'. Their actions demonstrate a deep understanding of the issue and reflect a strong sense of environmental responsibility. They are not only aware of the complexities of climate change but also engage in thoughtful consideration about how to address it. This group stands out for its ability to align its high level of awareness with effective and responsible actions. Trott (2020) finds that such engagement is likely due to a combination of strong climate change awareness and a sense of empowerment to take action. Harker-Schuch (2019) emphasizes targeting young adolescents as key agents of change, aligning with this cluster's proactive nature. These children's actions are not just superficial; they are underpinned by a well-informed understanding of climate change and its complexities. The Reflective Cluster, with their high understanding and proactive action, can benefit from Monroe et al. (2019)'s suggested focus on addressing misconceptions through advanced, thought-provoking discussions and activities. Incorporating complex, real-world scenarios in the curriculum and encouraging these children to develop and implement their own climate action projects can foster a deeper understanding and commitment. Monroe et al. (2019) also highlights the importance of interactive learning experiences, such as working on real-life environmental problems, which could further enhance the proactive nature of this group.

Impulsive Cluster (27.6%): Active engagement, limited understanding.

This cluster is characterised by their active engagement in matters related to climate change, but they possess a limited understanding of its complexities. This is in contrast to Kuthe et al. (2019)'s 'Charitables', who are active but not necessarily driven by the highest level of concern. The term 'Impulsive' highlights their tendency to take action without fully grasping the nuances and complexities of climate change. Their actions might be driven by external influences like peer pressure or adult behaviour. Although their actions are enthusiastic, they are not always well-informed or strategically thought out. This impulsiveness leads them to engage in activities that might not be the most effective or appropriate responses to the challenges posed by climate change. Stevenson et al. (2019) indicate that this impulsiveness might be influenced by personal beliefs and family influence. Tayne et al. (2020) suggest that educational approaches emphasizing the complexities of climate change could help this cluster take more informed actions. Monroe et al.'s (2019) emphasis on addressing misconceptions is particularly relevant for the Impulsive Cluster. Educational strategies should focus on expanding their understanding of the complexities of climate change, moving beyond superficial engagement. This could involve integrating curriculum elements that explore the scientific, social, and economic aspects of climate change in an age-appropriate manner. Monroe et al. (2019) suggest using engaging teaching methods, such as role-playing or simulation games, to help these children grasp the nuances of climate change and the importance of informed action.

Implications of the Findings: A Tailored Approach to Climate Change Education

The implications of this study's findings on climate change awareness among Japanese primary school children are significant and multi-dimensional, offering valuable insights for educators, policy makers, and researchers in the field of CCE.

1. **Importance of Tailored Education:** The identification of four distinct clusters of children based on their climate change awareness underscores the necessity of tailored educational strategies. Monroe et al. (2019) emphasises the effectiveness of customized educational approaches. For instance, the Contemplative Cluster, with high awareness but low action, may benefit from participatory and deliberative educational methods that provide both knowledge and motivation to act. In contrast, the Moderate-Apathetic Cluster requires strategies that make climate change concepts personally relevant and urgent, as they exhibit moderate awareness and minimal action.
2. **Bridging Knowledge and Action:** The study reveals a gap between knowledge and action in some clusters, particularly the Contemplative and Moderate-Apathetic groups. This suggests that CCE should not only focus on imparting knowledge but also on fostering the skills and motivation for tangible action. As Monroe et al. (2019) suggest, engaging in hands-on projects and real-world problem-solving can be particularly effective. This approach aligns with Trott's (2020) proposition that participatory methods in educational settings can empower children, enabling them to overcome barriers to action.
3. **Enhancing Understanding of Complexities:** For clusters like the Impulsive group, who exhibit active engagement but limited understanding, the findings highlight the need for education that deepens comprehension of the complexities of climate change. Stevenson et al. (2019) indicate the importance of addressing misconceptions and expanding understanding, suggesting that curriculum elements exploring the scientific, social, and economic aspects of climate change in an age-appropriate manner are crucial.
4. **Empowerment through Proactive Learning:** The Reflective Cluster, characterized by a balanced blend of high perception and proactive action, demonstrates the potential for CCE to cultivate informed and responsible environmental stewards. Educational strategies for this group should include advanced discussions, project-based learning, and real-life environmental problem-solving, as suggested by Monroe et al. (2019).
5. **Implications Beyond Primary Education:** The findings have broader implications beyond primary education. Early learning experiences form a foundation for knowledge and skills that are carried into adulthood, as argued by Miyashita (2020). Therefore, effective CCE in primary schools can have a long-term impact on societal attitudes and actions towards climate change.
6. **Role of Emotional Engagement:** The study also highlights the importance of emotional engagement in CCE. The Perception about Climate Change

factor, which includes emotional responses, suggests that addressing the emotional dimensions of climate change can be as important as cognitive understanding. Etkin & Ho (2007) discuss the significance of risk perception, indicating that emotional engagement can enhance the effectiveness of CCE.

7. **Global Relevance and Adaptation:** The study's findings, while focused on Japanese primary school children, are applicable worldwide. The tailored educational strategies based on awareness clusters can be adapted to various international contexts. This adaptation should consider local cultures, environmental challenges, and educational systems to ensure the effectiveness and inclusivity of climate change education globally.

In conclusion, this study provides valuable insights for the development of effective CCE curricula, tailored to meet the diverse needs of different student profiles. It emphasizes the need for an integrated approach that combines knowledge, emotional engagement, and action-oriented learning to effectively prepare the younger generation to tackle the challenges of climate change.

Limitations and Recommendations

Despite its valuable contributions, this pilot study on climate change awareness among Japanese primary school children has certain limitations. The sample was confined to children from only three schools in Hiroshima prefecture, which may not represent the full spectrum of climate change awareness profiles that might exist across different regions in Japan or in other countries. This limitation raises concerns about the breadth and applicability of the findings beyond the specific context studied. Moreover, the study's focus on primary school children leaves the awareness profiles of older students unexplored. Adolescents and teenagers, who are at different stages of cognitive and emotional development, could exhibit varying levels of awareness and engagement with climate change issues. Addressing these limitations requires future research to consider a more diverse and extensive sample. Including children from various geographical areas and different educational stages would provide a more representative understanding of climate change awareness among a broader population. Longitudinal studies would be particularly beneficial, offering insights into how climate change awareness develops over time and the long-term impact of early education on attitudes and behaviours. Furthermore, incorporating qualitative methods like interviews or focus groups could deepen the understanding of children's thoughts and feelings about climate change, adding a rich context to the quantitative findings. Overall, while this study lays an important foundation in integrating climate change education into primary school curricula, expanding the research scope would enhance our understanding and guide more effective educational strategies and policy-making. This effort is critical for preparing a more informed and proactive younger generation in addressing the challenges of climate change.

Conclusion

RQ1 assessed the Climate Change Awareness Scale (CAS) for Japanese primary school children, confirming its reliability and validity. RQ2 used cluster analysis to categorize children into four distinct groups - Contemplative, Moderate-Apathetic, Reflective, and Impulsive - based on their climate change awareness. This categorisation provides a nuanced understanding of the various levels and types of climate change awareness among Japanese primary school children. The study's findings have significant implications for the integration of climate change education into primary school curricula. By recognizing the different awareness profiles of children, educators and policymakers can tailor educational content and teaching methods to address the specific needs and characteristics of each group. This targeted approach could enhance the effectiveness of climate change education, ensuring that it not only informs but also actively engages young learners in meaningful climate action. Moreover, these insights can aid in developing global strategies for climate change education, as the identified profiles may have relevance beyond the Japanese context.

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Developing a Framework to Evaluate Open Schooling for Science and Sustainability Education

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The coronavirus pandemic demonstrates the importance of having highly qualified scientists but also the necessity to have scientifically literate people that can understand the implications of scientific advances and make informed decisions. Open Schooling (OS) has been envisioned as a powerful approach to foster relevant and meaningful science learning and to increase society's engagement in science and education. Within the context of a European project to improve science education through OS, this work describes the development of a questionnaire to evaluate the effects of OS on students' interest, scientific literacy and understanding of current environmental problems and their role in solving them. In addition, a framework for the development of case study will provide rich qualitative data allowing the identification of key factors and hindering circumstances, while providing a better understanding of how to enhance science and sustainability education through OS.

Keywords: Open Schooling, Scientific Literacy, Sustainability Consciousness.

Introduction

Europe is facing a shortfall in science-knowledgeable people at a time when it needs ever more scientists and a science literate society. In response to this shortfall, Open Schooling (OS) has been proposed as a powerful way to increase the uptake of science careers and to improve science literacy for all. In particular, European projects funded under OS calls are expected to involve learners in meaningful real-life problem-solving situations in collaboration with various stakeholders, to ensure that young people and adult learners alike are motivated to learn and to be fully equipped to engage in scientific discourse in society (European Commission, 2022).

According to Sisnetwork, (2016), the term OS refers to institutions that promote partnerships in education with families and different agents of the community as part of their development. Therefore, it refers to environments where schools, in cooperation with other stakeholders, become agents of general well-being; families are encouraged to become real partners in school and professionals from enterprise, civil and wider society are actively involved in bringing real-life projects into the classroom. By definition, OS is aligned with context-based learning (King & Ritchie, 2012), providing meaning and relevance to what has to be learnt (Broman et al., 2022). OS offers powerful opportunities for competence development, STEM learning for responsible citizenship (Mass et al., 2022) and service learning (Taylor & Lelliott, 2022), placing schools as central hubs of community well-being (European Commission, 2022).

Closely connected to the vision of schools as agents of change for a better and more sustainable world is the notion of education for environmental citizenship. When students get engaged in the investigation of local socio-scientific issues related to sustainability problems through OS, they increase their sustainability consciousness and acquire the attitudes and skills necessary to act as responsible and well-informed environmental citizens (Ariza et al., 2021a, Ariza et al., 2021b).

Promoting scientific literacy and sustainability consciousness through school community projects

The European project MOST (Meaningful Open Schooling Connects Schools To Communities) responds to the previously mentioned needs by empowering teachers and schools to link mathematics and science learning to the solution of nearby environmental problems (Romero-Ariza et al., 2023). Funded by H2020 Framework Program, the MOST project involves experts from 23 institutions of ten different countries in the development of tools, guidelines and instruments to improve STEM and environmental education through the development of Open School Projects (SCP). In particular, SCP are expected to improve students' interest in science and their perception of relevance of what they learn at school, along with their scientific literacy.

SCP are also expected to improve sustainability consciousness (Romero-Ariza, 2023). Human consciousness is exemplified by all things we can observe or experience (Velmans, 2009), thus sustainability consciousness refers to human experience or the awareness of sustainability phenomena. There are previous works (Ariza et al., 2021a; Gericke et al., 2029), that have operationalized sustainability consciousness into a research tool providing the possibility to measure knowingness (recognition of the importance of sustainability), attitudes (the attitudes towards sustainability), and self-reported behavior (the willingness to act towards a sustainable future) in relation to the three pillars model of sustainable development dimensions (environment, economy and society).

In the MOST project, students actively engaged in the investigation of local problems related to waste and energy in order to co-design with experts and other members of the community, sustainable solutions, while meaningfully applying STEM knowledge and skills, through the implementation of School Community Projects (SCP).

SCP directly speak to students concerns and needs related to improving their close surrounding in the construction of a more sustainable world. In the process of search and development of creative solutions, schools collaborate with different agents in the co-creation, negotiation and implementation of these solutions. Students take an active role meaningfully applying STEM knowledge and competences through the whole process, increasing their sustainability consciousness and becoming aware of their important role in solving current societal and environmental problems (Romero-Ariza, 2023).

This work describes the development of a framework to evaluate the impact of SCP on participants and to learn some lessons about how to best support OS for science and sustainability education. Precisely, the evaluation framework was intended to respond to the following research questions:

1. How do SCPs affect students' attitudes and beliefs about science, scientific careers and the relevance of science and science education for their lives?
2. How do SCPs affect scientific literacy and participants' awareness with regards to environmental challenges and their role in finding solutions?
3. How do participants perceive and experience SCP and what are the characteristics of good SCPs and the main barriers for a successful implementation and networking?

Developing an Evaluation Framework for Open Schooling

In order to address the previously formulated research questions, we proposed a pre/post research design to evaluate the effect of SCP on students' attitude towards science, their perception of relevance of what they learn, along with their scientific literacy and sustainability consciousness.

To develop a specific valid and reliable pre/post questionnaire, we first revised the specialized literature to provide theoretical framework for the definition and measurement of the intended constructs: interest and positive orientation towards science and scientific careers, motivation for learning (task value and relevance), scientific literacy and sustainability consciousness.

Measuring students' scientific literacy through a close questionnaire was a big challenge. Scientific literacy has been defined as what people need to understand and appreciate in daily situations and contemporary issues related to science and technology, in order to act in an effective and informed way (Romero-Ariza, 2017). According to the PISA framework (OECD, 2016), scientific literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to i) explain phenomena scientifically; ii) evaluate and design scientific enquiry; iii) interpret data and evidence scientifically. Considering these indicators, we proposed a sub-scale of 8 items to capture possible changes in students' capacity to evaluate enquiry and explain phenomena scientifically.

On the other hand, sustainability consciousness refers to human awareness of sustainability phenomena. Previous questionnaires have been described to measure this construct (Ariza et al., 2021a; Gericke et al., 2028), providing us with a basis for the development of a 12 items sub-scale to evaluate changes in beliefs, attitudes and sustainability behaviours, as a result of the participation in SCP.

Finally, two other sub-scales to evaluate learning relevance (4 items) and students' interest in science (4 items) have also been developed, partly based on previous works (Summers & Abd-El-Khalick, 2018).

The first draft of the questionnaire was subjected to external validation by experts and then piloted with a sample of students covering the age range of those participating in SCP (N=333). A principal component analysis (PCA) and an exploratory factor analysis (EFA) were conducted on the pool of 28 items, with orthogonal rotation (varimax). Finally, reliability and internal consistency were determined for the different sub-scales related to any of the principal components. The different sub-scales included in the questionnaire had reliabilities from good to high (0.77-0.91), with an Overall Cronbach $\alpha = .89$. In addition, results from PCA and EPA analysis shows items that cluster on the same components suggesting a robust structure backed up by statistical evidence and a set of factors aligned with the theoretical constructs underlying the design of the instrument. More details about the design, piloting and validation of the questionnaires can be found in Romero-Ariza et al., (2023).

To capture the complexity and variety of SCP that could arise from different educational contexts and needs, a case study approach was also proposed. Case studies were selected purposely to illustrate typical, extraordinary cases or good practices and to offer an in-depth view that allows the understanding of the key characteristics of good SCP, and the identification of supporting and hindering factors. Special attention was paid to ensuring descriptive validity (factual accuracy), interpretive validity (triangulation of sources and different types of data) and theoretical validity (consistency with theory and previous publications).

The agreed categories to characterise the school community project central to any case study were: students' educational stage, duration of the project, level of students' agency and community members' engagement, authenticity and relevance of the final outcomes and indicators of STEM learning, understanding of current environmental problems and students' role in solving them.

Applying the evaluation framework: the case of the MOST project

As described in the previous section of this paper, the main aim of the MOST evaluation concept was to provide a research design and a collection of evaluation instruments that fulfil the purpose of the project evaluation.

The project evaluation had a twofold purpose: on one hand it intended to measure the project's short-term impact in terms of the promotion of science literacy, perceived relevance and positive attitudes towards science and scientific careers, as well as increased sustainability awareness and individual capacity to act on environmental issues.

On the other hand, the evaluation of the MOST project should provide a collection of multiple case studies from ten European countries, illustrating how School Community Projects (SCP) may be articulated to adapt to different regional contexts, as well as barriers and supportive aspects for their successful and productive implementation.

As a consequence of the participatory development of the evaluation concept, a collection of research questions and evaluation instruments was provided. The collection of evaluation instruments included a template for reporting on case studies, questionnaires for the main participants (students and teachers) used either as pre/post instruments (student questionnaire) or just post instruments (teacher questionnaire), along with guidelines and basic questions for the semi-structured interviews of a wide range of stakeholders using focus group discussions (teachers, students, school leaders, MOST advisors, family members as well as representative from the scientific community, business or policy sectors).

As previously stated, the qualitative data collected through a collection of 30 case studies around the development of particular SCP, conducted within the MOST consortium, intended to respond to the following research question: How do participants perceive and experience SCP and what are the characteristics of good SCPs and the main barriers for a successful implementation and networking?

It is important to note that all SCP shared a similar approach to engage community members in the solution of relevant local sustainability problems and follow a common pedagogical framework based on project-based active and reflective learning. However due to the wide variety of SCP conducted in the ten partner countries, and their differences concerning the age of the participating students, the socio-cultural context in which the projects were embedded and their duration in time, among other circumstances, we decided to develop closer looks based on the analysis of regional case studies, combining both qualitative and quantitative data.

On a general level, quantitative data from the pre/post evaluation of different SCP show positive effects on students' science literacy, perceived relevance and positive attitudes towards science and scientific careers, as well as an increased understanding of sustainability problems related to waste and energy management and enhanced awareness of their personal role in solving them. However, the magnitude of these effects and the gain patterns depend on the characteristics of the SCP and the socio-cultural contexts where it was implemented. More details about the concrete impact of the project in any of the national contexts where the project was implemented is offered in the final evaluation report of the project and will be rigorously describe in a forthcoming publication.

The qualitative data from the case studies, allowed us to better understand how the contextual factors affect the consequent outcomes. The main aim was to look at how SCP were experienced by participants and finally, what were the key features of good SCP and the main barriers for a successful implementation.

Regarding the first question, the content analysis of participants' quotations revealed a predominance of feelings of proud and enjoyment and a sense of relevance and impact of what has been achieved.

In relation to the characteristics of good SCP, the qualitative analysis shows the importance of planning in advance and getting the school and community support, as well as linking the project to both local problems relevant to those involved and the school curriculum. Participants also expressed a desire to share and disseminate results, to keep on working in this way and to do more about the issues approached in a near future.

Regarding the main barriers for a good implementation, teachers usually refer to lack of time or experience, a rigid school curriculum and organization and sometimes, difficulties to collaborate with other colleagues and engage external agents. They require recognition to their efforts and bigger support and flexibility to run such projects.

In relation to students' learning outcomes, the complementary qualitative analysis of teachers', students' and parents' perceptions provide nice evidence about how SCP offered meaningful contexts to apply mathematics and science content knowledge and skills to solve relevant local problems, and to what extent these kind or projects make students develop interesting transdisciplinary skills related to teamwork, communication, creativity, and critical thinking. Finally, participants' quotations illustrate how those experiences help students understand the basis of some sustainability problems and make them to engage in active mitigation actions or the search for solutions.

Conclusions

This work addresses the challenge to evaluate OS for STEM and sustainability education providing a robust and innovative questionnaire to measure the impact of OS on students' scientific literacy, sustainability consciousness, interest in science and perception of relevance of what they learn. In addition, a framework for carrying out case studies was developed. The collection of both quantitative and qualitative data made it possible to combine the strengths of both approaches and helped us to overcome their particular weaknesses, allowing us to address complex research questions, like the ones framing this work (Creswell et al., 2011). The application of this framework to the evaluation of the MOST European project provided research evidence of the positive impact of the project on students' interest in science and scientific literacy, the perception of relevance of what they learn and the understanding of current environmental and sustainability problems and the appreciation of their role in solving them. In addition, the application of the framework to 30 case studies conducted in 10 different countries, provided rich pictures of how open schooling can support these relevant learning outcomes.

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Favoring School and Community Synergies for Addressing Sustainability Issues in the Town

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On Monday, the school opens its doors and students and families find that everything is full of rubbish; curiosity assaults the walls of the center. This is the beginning of a school community project (SCP) carried out in a small town in Jaén (Spain) following the open schooling features. The context, which initially only affected the school, spread throughout the city. The design of the SCP by teachers, supported within a professional development course, as well as the involvement of students and the community, allowed open schooling. Within the context of a European project, a collection of case studies has been developed in order to illustrate good practices and understand how to improve STEM education through open schooling. This paper presents the analysis of one case to unveil the perceptions of the participants, the impact on students' learning, their role in solving problems, as well as key features of good SCP and the main barriers for a successful implementation

Keywords: Open schooling, case study, sustainability

Introduction and Theoretical Framework

Society is in need of scientifically and environmentally literate citizenship, therefore, scientific education must go beyond the classroom. Methodological approaches such as service-learning or project-based learning are increasingly common in schools. Through these educational actions, schools direct their efforts towards providing a service for the community. While still being an effective approach for students to understand the usefulness of science for the benefit of the community, these actions are generally developed without regard to social needs and without taking into account the benefits that the society could contribute to the development of the project and, therefore, to the resolution of the problem.

Open Schooling (OS) is a way of responding to this social need aiming for context-based, relevant, competent and service scientific learning (King & Ritchie, 2012; Sotiriou & Cherouvis, 2017; Broman et al., 2022), which could be materialised in School Community Projects (SCP). Whithin this kind of project, students act as change agents by tackling an environmental problem that directly affects their community, seeking co-created solutions with the community.

To analyse the impact of SCP, a mixed method evaluation framework has been developed in the context of a European project, combining the strengths of quantitative and qualitative approaches and minimizing weaknesses (Devetak et al., 2010). This work shows the case study of one SCP as way of taking shape the qualitative research to draw valid conclusions around next four research questions: 1) How do SCPs affect students' attitudes and beliefs about science, scientific careers and the relevance of science and science education for their lives? 2) How do SCPs affect science literacy and participants' awareness with regards to environmental challenges and their role in finding solutions? 3) What are the characteristics of good SCPs and the main barriers for a successful implementation and networking? 4) How do participants perceive and experience SCP?

Methodology

Context and intervention

Teachers have guided the SCP as an activity included in an in-service teacher professional development course contextualized in a European project (MOST, "Meaningful Open Schooling connects schools to communities"). In this context, teachers, as a community of practice, investigate and design a school community project from co-creation with other colleagues and agents outside the educational community. In addition, they put the SCP into practice in their classrooms, share it with the rest of the members of the community of practice and, finally, they analyse it from the point of view of profits for their professional activity. The design of this training action for in-service teachers has characteristics that, based on their beliefs, affect the development of their teaching competencies (Abril et al., 2014; Maass et al., 2022).

Therefore, the school's teaching staff designed the SCP developed in their school located in a little town in the South of Spain. This village maintains a rural economy but their residents neglect aspect of the environment. The school involved was motivated towards the implementation of student-centered pedagogies, addressing diversity and students' needs and interests. The SCP central to this case study involved 180 children aged 3-12, and the complete teaching staff participated in the project for over nine months, engaging 10 participants from the community, including the Mayor, members of the local police and families. The triggering action of the project was that the playground appeared full of garbage, which surprised and deeply affected the students and families. The initial question that drove the whole project was what could we do in this situation? Based on this question, other more specifics were formulated by the students (what can we do with the garbage? Could we reuse or recycle it?

There is also garbage in the town, how can we help the town to recycle more? What can we do to make the town's air cleaner?) From this moment on, the students formed the Board of Students' Delegates and took the initiative. The proposed solutions and the activities carried out are discussed below.

Sources of information and qualitative analysis

The case study involved school observations, the analysis of students' work and two semi-structure group interviews. The first one involved six students from different ages members of the Board of Students' Delegates actively involved in the SCP. The second one two teachers (one with extensive experience in the project), the school leader and an external advisor. All people selected for the interviews were representative of their segment. The questions posed in the group interviewed were related to the design of the SCP, the role of participants, the proposed solutions to address the problem and their connection with the curriculum, the dissemination of the SCP and finally, positive aspects and main barriers for implementation.

The interviews took place at school, for about 30 minutes, they were recorded, transcribed and submitted to content analysis, drawing on participants' quotations whenever was necessary to allow low inference conclusions. Special attention was paid to the accurate description of facts (descriptive validity), interpretations triangulated and supported by different agents, researchers, sources of information and data (interpretative validity) and theoretical validity, discussing results in light of relevant previous publications.

Results and Conclusions

From October 2021 to June 2022 the SCP "Jamilena 2030, you decide" took place. In its design, the characteristics of a good SCP were taken into account. Thus, synergies between the school and the community appear to solve a problem that, in the first instance, arose within the school, but later spread to the entire town.

As mentioned previously, the problem was presented by the teacher staff; in the morning, the school yard appeared full of garbage. From that moment on, the students took the initiative of the actions they had to carry out. Although at first, the problem was located in the school center, it spread to the rest of the town with the guidance of the teachers. It goes from a specific problem of the Center to a problem of all the inhabitants, the project opens to the community. At this point, teachers guided the students towards the participation of citizens, but preventing the students from demanding specific help. That is, at this moment teachers became an essential link, promoting the contribution of citizens from very different points of view and each person contributed from their specialization. It was very important to transform the demand for help, phrases like "please, we need you to do X to help us" were transformed into "we have a problem, how could you help us, please?" Table 1 shows the temporal distribution of some of the project milestones.

Table 1. Chronological order of the SCP events, actions specifying each event and participants involved.

Event	Action	Participants
Invite and Co-creation	Selection of the theme to improve the local environment, entry event in close and significant context, connection with the curriculum.	Teachers from different schools, external advisor (*)
SCP launch	Introduce the issue to the students: Piles of waste appears in the school.	Students and teachers
Co-creation	Board of Students' Delegates, identification of the question to be investigated and the procedure to apply.	Students
Act	Proposal of mitigations actions to solve the problem	Students
Invite and Co-creation	Agree on the actions to be carried out with the community.	Students, teachers, community members
Act and Share	Inform the community, bicycle parking, safe route, school garden, reforestation in public areas, healthy breakfasts.	Students, teachers, community members
Evaluate	Collection of evidences and feedback on the implementation of the SCP.	Teachers from different schools, external advisor (*)
Share	Share SCP in a regional SCP Fair.	Students
Evaluate	Analysis of the experience lived by the participants.	School leader, teachers, students, external advisor

Participants promoted different co-creation events. In the first one, the initial design of the project was addressed specifying, among other aspects, the learning that was intended to be developed such as Ecology (waste, air pollution, healthy living and human anatomy, botany and taxonomy, etc.), Mathematics (statistics, calculus, etc.), Chemistry (periodic table, chemical reactions, etc.), Language (communication) and Arts (design and elaboration of visual messages). Co-creation and evaluation events (asterisks in Table 1) were addressed within the professional development course, organized by the Teachers' Center including immersive activities, which, together with the support and feedback generated by the group, made the course a great opportunity to learn about OS. The third event of co-creation arose from the students themselves, given the need to ask the community. The approach to the community of the problem in an open way, without specific demands, favored the appropriation of the problem by the community supporting a new point of view.

Regarding the students' agency, they did not choose the topic, but they took an active role in proposing and developing solutions. Out-school agents took a relevant part in the co-creation process and in facilitating procedures to carry out solutions. Regarding STEM learning when developing the SCP, explicit mathematics and science learning took place.The results of the content analysis of the two interviews carried out are presented below. Table 2 shows the frequency and number of interventions for each category which are related to each of the research questions. Of the 22 categories identified, only two refer to negative characteristics, in the table they are identified with (-).

Table 2. Results of the content analysis of the interviews.

Aspect	Category	N	Frequency
1) Science / Scientific careers / Relevance	Positive feelings - it was worthy	3	4,69
2) Science literacy and awareness to env. challenges	Soft skills and other learning outcomes	2	3,13
3) Characteristics of good SCPs	Relevance/impact	6	9,38
	Students' ownership, commitment & autonomy, self-confidence and	6	9,38
	Planning ahead and school support	4	6,25
	Engagement and support of community members	4	6,25
	Dissemination	4	6,25
	Co-creation	3	4,69
	Team work and Communities of practice	3	4,69
	Real life-problems	3	4,69
	Pedagogical support	3	4,69
	Impact on teacher PD and collaboration	3	4,69
	SCP changed participants - impact	2	3,13
	Difficulties to engage stakeholders (-)	2	3,13
	Connection with school curriculum	2	3,13
	Different ways of learning and inclusion	1	1,56
4) Participants perceive and experience SCP	Motivation and encouragement	3	4,69
	Feeling that it was worthy, satisfaction, proud, gratitude	3	4,69
	A desire to do more	3	4,69
	Enjoyment, enthusiasm	2	3,13
	Lack of support and recognition (-)	2	3,12
	TOTAL	64	100

In general, participants mainly refer to themes related to the characteristics of a good SCP. For its part, there are few comments related to how SCP affect students' attitudes and beliefs about science, scientific careers and the relevance of science and science education, as well as about how the SCP affects science literacy and participants' awareness about environmental challenges. There are some comments about how participants perceive and experience the SCP. In this respect, teachers comment that there is a lack of support and recognition of effort made.

In general, School leaders and teachers perceive that they have changed, the project has generated an atmosphere encouraging teachers to work in this way and students have felt responsible for their actions. For their part, the students were engaged from the beginning, they felt empowered, grateful for this way of learning and do not hesitate to invite the rest of the students to learn by helping society. All those interviewed stress the need for the community to be present in the projects. Regarding learning, students understand that they worked on science and mathematics thanks to the SCP.

Lastly, challenges have arisen, some of which were overcome throughout the project, and others are aspects to be improved for the next actions. The teachers emphasize the need to activate all the classmates at the center so that they get involved in this type of methodologies and underline that the main problem is taking the first step. This handicap has been addressed by establishing time for SCP, setting a time on Fridays for co-creation, discussion and workshops. In order to illustrate these results, Table 3 presents some examples of quotations from the different participants.

Table 3. Quotations examples

Quotation	Participant
"Something has changed in the school in recent years towards active methodologies"	Early childhood teacher
"The learning has permeated them, I see more critical thinking, dynamic attitudes, students are more involved in the school"	Primary teacher
"We would like to tell other students to work like us because it helps the environment"	Student
"There is no better teacher than a son/daughter"; "For me, families have to be part of the school"	Primary teacher
"We did a survey and we saw how many people used the car and how many came walking"	Student 11 years old
"I said to plant trees to have the good oxygen and the air to be better"	Student 4 years old
"The main challenges of this school, leaving the comfort zone, involving and raising awareness in the community". "There has been an organizational change, we established a meeting for teachers on Fridays to adapt the actions to the curriculum"	School leader

“Finding yourself with a group of people who share your work approaches is comforting.”	Teacher
“The learning has permeated them, I see more critical thinking, and dynamic attitudes, students are more involved in the school.”	Teacher
“Two grandmothers were talking...that’s the MOST thing...like they were talking about a well-known TV show.”	Student
“Families give you things without your asking if they know you work for projects…”	Teacher
“The students planted the seed and make it germinate.”	School leader
“A project is a blank sheet of paper and experience helps you become fluent in writing it.”	School leader

Results obtained through descriptive and interpretative validity shown that the SCP “Jamilena 2030, you decide”, firstly, promotes partnerships with families and community members, develops context-based learning and meaning and relevance to what has to be learnt. Further, it offers opportunities for STEM learning for responsible citizenship, competence development and service learning (all of them key features of good SCP) (Sotiriou & Cherouvis, 2017; Broman et al., 2022). Secondly, this OS project has had an impact on students’ learning and students’ understanding of sustainability issues and the participants’ role in solving them. Finally, although barriers have been detected, the school community has developed tools to solve them. Thus, we believe that this case is a good example of OS, generating synergies between the school and the community to solve environmental problems that are close and significant to all.

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Conceptual Understanding of Climate Change of German A-Level Students

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The anthropogenic climate change confronts humanity with unprecedented challenges. Understanding the scientific principles behind climate change is a prerequisite to reach higher acceptance of measures and to motivate individuals to climate-friendly behaviour. Concept inventories serve to reliably evaluate the understanding in large scale studies. Several such concept inventories exist, most recent addition is the up-to-date climate change concept inventory "CCCI-422" in German. The research aim is: Which student conceptions are prevalent among (German) A-level students at the end of formal schooling? And how do students rate their knowledge about climate change and how does their rating relate to their conceptual understanding? The sample consists of 501 A-level students of five German upper-level secondary schools. A student's conceptual understanding of climate change is defined as the person ability measured with the CCCI-422 using Rasch analysis. Students answered on average 14 of the 36 items correctly. Most difficult item with an item difficulty of 3.25 is the question, how high the percentage of greenhouse gases in the atmosphere is, with more than half of the students choosing between 5% and 55%. Also, roughly 30% of the students hold the false conception of the ozone hole being responsible for the strengthened greenhouse effect. On average, the students self-rate their knowledge pre 60% and post 33% after taking the inventory thus becoming more realistic. The correlation of person ability and pre- or post-self-assessment is in both cases significant, yet small in effect size. Overall, the CCCI-422 seems difficult for the A-level students, which sheds some light on all formal schooling in Germany.

Keywords: Climate change, conceptual understanding, diagnostic tools

Background

The anthropogenic climate change confronts humanity with unprecedented economical, ecological, and social challenges (Schreiner et al., 2005; IPCC, 2018, 2021). Climate change is particularly important for young people, whose lives will be shaped by climate change impacts in the future. Although, more developed knowledge about climate change does not necessarily lead to more climate-friendly behaviour (e.g. Hornsey et al., 2016), understanding the scientific principles behind climate change is a prerequisite to reach higher acceptance of measures and to motivate individuals to climate-friendly behaviour (e.g. Bord et al., 2000).

Student's conceptions are regarded as highly relevant for learning in a way that students' prior ideas are influential in supporting or constraining learning (Vosniadou, 2009). Knowing the conceptual understanding of climate change of (young) learners can not only guide future instruction but also assess previous instruction on climate change.

Student Conceptions can be assessed with a variety of measures including concept inventories or interviews. Concept inventories serve to reliably evaluate the understanding in large scale studies to elicit misconceptions and to distinguish them from lack of knowledge (Schecker & Gerdes, 1999). Over the last years and decades, several such concept inventories for the topic of climate change have been developed in English (e.g. Keller, 2006; Arslan et al., 2012; Jarret & Takacs, 2020). Most recent addition is the up-to-date and psychometrically refurbished climate change concept inventory "CCCI-422" in German (Schubatzky et al., 2023).

Typical student conceptions on climate change include a confusion about climate and weather, a confusion with the ozone hole ("it gets warmer, because more shines in", Niebert, 2010), a reflection conception for the greenhouse effect or a false distinction between natural and artificial CO2 with the latter being unreachable for plants or a general underestimation of effects e.g. of trace gases on the climate on Earth.

Our research aim is to assess the conceptual understanding of the scientific principles of climate change of German A-level students. Such A-level students represent the end of formal schooling and can therefore shed light on the effect of all formal schooling on students' conceptual understanding. There are two guiding research questions: Which student conceptions are prevalent among (German) A-level students at the end of formal schooling? And how do students rate their knowledge about climate change and how does their rating relate to their conceptual understanding?

Design and methods

The sample under investigation consists of 501 A-level students of five German upper-level secondary schools (Gymnasium). The 501 students represent the complete A-level student body in their schools, except for random sick-leave students. The five schools are all well-situated in an urban setting in the state of North Rhine-Westphalia, Germany. Depending on their choices, some students have year-long subject schooling in physics with up to five lessons per week, whereas some students had their last formal schooling in physics several years ago. 71.8% believe that current climate change is man-induced, with another 25.5% believing in a mix of man-induced and natural causes, and four of the 501 students believing only in natural causes and nine students feeling unsure.

A student's conceptual understanding of the scientific principles behind climate change is defined as the person ability measured with the CCCI-422 using Rasch analysis. The CCCI-422 was developed following AERA's "standards for educational and psychological testing" (AERA, 2014) concerning the development of concept inventories. Central concepts were derived from literature search and expert interviews (n=8 climate scientists from Austria and Switzerland) resulting in five concept areas: 1. Facts of the atmosphere of planet Earth. 2. Distinction between weather and climate. 3. Earth's climate as a system. 4. The greenhouse effect and 5. The carbon cycle. Distractors were derived from 40+ interviews with open ended questions ending in 36 closed multiple-choice items concerning the five concepts with three to five distractors delivering alternative conceptions. Student knowledge self-assessment is operationalised as a single open question (0-100%) and tested prior and after the concept questions. The CCCI-422 was successfully tested for reliability and validity with almost 800 people of different ages and knowledge levels and can therefore be regarded as ready-to-use (Schubatzky et al., 2023).

The study follows a cross-sectional design. The learners were tested once online in-situ using LimeSurvey ® on their personal device with a test duration of about 20 minutes within two weeks prior to the summer holidays at the end of June 2022. The students were tested within one lesson in each school.

Planned analyses consist of performing a Rasch-analysis using RStudio and the TAM-package to obtain the person ability of each student. To obtain the prevailing conceptions about climate change descriptive analyses are planned regarding the five concept areas including the most difficult item(s) and regarding overarching ideas (natural – artificial, overestimation of effects, reflection conception, …). These overarching ideas were determined by discursive agreement among all four involved researchers. The students' knowledge self-assessment and its relation to their actual knowledge is obtained by correlating the person ability with both the pre- and post-self-assessment.

Results

On average, students solved 14 of 36 items correctly, that is 39%. Concerning the knowledge self-assessment, students prior to taking the inventory expected they would solve 60%, after having taken the test, they thought to have solved 33%. The difference in the students' knowledge self-assessment between pre and post is significant ($t(495) = 28.2$, $p < 0.01$) with an effect size of $d = 1.4$.

The correlation between the students' knowledge self-assessment and the person ability obtained by Rasch analysis is both pre and post weak, yet significant (pre: $r = 0.16$, $p < 0.01$; post: $r = 0.25$, $p < 0.01$).

Most difficult item with an item parameter of 3.25 is the question, how high the percentage of greenhouse gases in the atmosphere is, see table 1. Answer choices range from "less than 1%" to "more than 55%" with more than half of the students choosing between 5% and 55%.

Table 1. Answer distribution of item A3, the most difficult item of the concept inventory and the content area 'The Atmosphere of our Earth'. Correct answer in bold.

(A3) Treibhausgase sind Bestandteile der Atmosphäre, die das Klima besonders beeinflussen. Wie hoch ist der Anteil dieser Treibhausgase in der Atmosphäre? [Greenhouse gases are constituents of the atmosphere that affect the climate. How high is the percentage of greenhouse gases in the atmosphere?]	
Answer options [Antwortmöglichkeiten]	Absolute number of respondents (n_{sample}=501)
a) More than 55% [Über 55%]	90
b) Between 30% and 55% [Zwischen 30% und 55%]	213
c) Between 5% and 30% [Zwischen 5% und 30%]	139
d) Between 1% and 5% [Zwischen 1% und 5%]	38
e) Less than 1% [Weniger als 1%]	**21**

Most difficult item in the concept area "greenhouse effect" is the question, in which form the Sun radiates the most energy on Earth. Answer choices include visible light, infrared, UV, and radioactive radiation. About two thirds of the students opt for UV-radiation, possibly confusing the harmfulness of (some) UV-radiation with the overall energy output of the Sun primarily in the visible regime. The alternative conception of the ozone hole being responsible for the strengthened greenhouse effect is held by roughly 30% of the students with less than 20% choosing the correct explanation.

Concerning overarching ideas, one idea may be summarized as 'Overestimation of CO_2' and can be traced back to items A2, A3, A3Z, and A4. In item A2, 45% of all students incorrectly chose that the air consists mainly of CO_2 and O_2. Items A3 and A3Z (the Z stands for zusätzlich [additional], because we added this item after piloting of the CCCI-422) similarly ask how high the percentage of GHGs in the atmosphere is now and was before industrialization. We reported above that more than 60% of students think that the percentage of GHGs in the atmosphere of planet Earth now is 30% or more and 26.4% of students think it was more than 30% before industrialization. Last item is A4, asking which GHG is the most abundant in the atmosphere (H_2O, CO_2, CH_4, O_3) where 69% of students chose CO_2 as the most abundant GHG with water vapour being the correct answer. We summarize the student performance with respect to these four items A2, A3, A3Z, and A4 as ‘Overestimation of CO_2’.

Another overarching idea may be summarized as ‘Reflection as main process of the greenhouse effect’ and can be traced back to items GH1, GH5, GH6, and GH7. In item GH1, asking which statement describes the greenhouse effect on Earth best, 30.5% of students chose that reflection causes the greenhouse effect on Earth. In item GH5, asking how green-house gases interact with incoming visible solar radiation, 37.7% of students chose that greenhouse gases reflect incoming visible solar radiation. In item GH6 46.7% of students think that greenhouse gases reflect visible solar radiation once reflected off Earth. And finally, in item GH7 43.5% of students chose that GHGs reflect the Earth’s thermal radiation. We summarize the student performance with respect to the four items GH1, GH5, GH6, and GH7 as ‘Reflection as the main process of the greenhouse effect’.

There are indications about further overarching ideas, of which one may be named “Ozone hole”, and another one as ‘Confusion about C and CO_2’.

Discussion

Concerning the first research question (Which student conceptions are prevalent among (German) A-level students at the end of formal schooling), the overall conceptual understanding of the scientific basics of climate change of German A-level graduates in the state of North Rhine-Westphalia seems low, because less than half the items were answered correctly (on average 14 out of 36 items). For comparison, Schubatzky et al. (2023) using the same climate change concept inventory CCCI-422 reported that an investigation of first semester civil engineering students (n=59) yielded on average 17 correct answers out of 36.

Several alternative conceptions known from literature can be confirmed with this sample. Concerning ‘The atmosphere of our Earth’, students in literature (Jarret & Takacs, 2020; Schubatzky et al., 2020) and a majority in our sample show an alternative conception that greenhouse gases constitute 30% or more of the atmosphere. This conception of overestimation of CO_2 is both present in the most difficult item ‘A3’ and the overarching idea ‘Overestimation of CO_2’. This conception may lead to appropriate actions concerning the reduction of CO_2-emissions. But people holding this conception may easily be fooled when climate change deniers perpetrate the myth that so little CO_2 in the atmosphere cannot make the difference (Höttecke & Allchin, 2020).

Other findings such as the ozone hole alternative conception, or a general reflection conception, have also been discussed in the literature and were found in this sample.

Concerning the second research question (How do students rate their knowledge about climate change and how does their rating relate to their conceptual understanding?), the self-assessment drops strongly and significantly from pre to post. For the post-assessment, the percentages of correctly answered items and self-assessment are closer together, the self-assessment with 33% is even below the actual performance with 39%, than for the assessment before taking the inventory. One wants to say that the self-assessment becomes more realistic after taking the inventory (due to the inventory?), but the self-assessment and the actual conceptual understanding are only weakly correlated for both instances in time, So, there are A-level graduates with high person ability but assess themselves low and vice versa. This can be problematic, because it looks like there are A-level graduates that may have the impression of being knowledgeable when in fact, they are not quite so knowledgeable.

To summarise, the conceptual understanding of the scientific basics of climate change seems to be rather low in this student population, which can be problematic. It also sheds some light on 12 years of schooling.

Concerning limitations, a curriculum analysis for the student population under investigation is pending. A detailed look into the mandatory curricula for e.g. Physics, Chemistry and Geography will give insight into what should have been mandatorily taught. If not much has been mandatory, the question arises, why teachers of these students did not take the pedagogical freedom to teach the scientific basics of climate change anyway. So, we conclude with the question: What are the internal and external conditions for successful teaching of the scientific basics of climate change?

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LAbs4Future – How Climate Change Knowledge can be Linked to Effective Action

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The two-day student laboratory Labs4Future for 14–15-year-old high school students tries to link knowledge about climate change with effective individual and societal action. Based on the theoretical framework Lessons4Action, which integrates environmental psychology, sociology and science education, we showcase how we try to transfer the theory into experiments and activities. Two hands-on elements are presented: The so-called Carbon Credits, an area visualization of daily personal and societal emissions - addressing Effectiveness knowledge and Perceived behavioural control. And, secondly, a Mystery about the complicated attribution of guilt for climate change related deaths, that is designed to link system knowledge with local affectedness, norms and attitude. The student laboratory has been tested and empirically evaluated in two iterations of an ongoing design-based research project with about 750 high school students. Central aims of the workshop were the critical discussion of the experiments and activities, the theoretical framework and how theory translates into practise.

Keywords: Climate Change, Climate Action, knowledge action gap

Introduction

Today's 16-year-olds will grow up to live in a world 2.5°C warmer than industrial levels. This will set off an unprecedented upheaval in food and water supplies, weather patterns and general living conditions. (IPCC et al., 2019) Luckily, as of now, we likely can still determine how far the changes reach.

Yet, as the UN negotiators of the 1.5° Paris Agreement, C. Figueres and T. Rivett-Carnac, put it:

> "We can no longer afford to assume that addressing climate change is the sole responsibility of national or local governments, or corporations or individuals. We can no longer afford the indulgence of feeling powerless." (Figueres & Rivett-Carnac, 2020).

Science education (and physics education in particular) is partly responsible for the lack of sufficient action against climate change. Whilst being the most institutionalized form of science communication, the years of lessons in school do not lead to sufficient action to avert the – scientifically clearly forecasted (Hagedorn et al., 2019; IPCC et al., 2019) – consequences and dangers.

Of course, the reasons for this are complex and not only within school. Yet, school is one of the fundamental pillars for socialisation and should strive for an education, that lays the groundwork for informed decisions and attitudes towards preserving stable environmental conditions.

What is needed is a new perspective on how to teach about the processes leading to climate change *AND* subsequently connect this knowledge to action. Fortunately, (environmental) psychology has been studying how to link knowledge with action.

We tried to integrate this theoretical knowledge into the framework Lessons4Action (Fig.1) and developed a two-day student laboratory Labs4Future implementing the framework: Designed for students of age 14-16 (usually school classes) the student lab takes place at Center for Maths and Science Education at University of Würzburg. The first day addresses earth system knowledge and is preparing for the second day about action and effectiveness knowledge. Pre-service science teachers instruct the students, help setting up experiments and working along the digital worksheets. The instructions, materials, and methods have been developed and iteratively adapted several times since 2022, with a total of about 750 participating students.

The workshop's central aim was to present two concepts that implement environmental psychology into lessons about climate change, based on the theoretical framework Lessons4Action:

1. A Mystery about the complicated attribution of guilt for climate change related deaths, of affectedness locally in Germany, which addresses norms, affectedness, and earth system knowledge.
2. The Carbon Credits, an area visualization of all kinds of daily personal emissions that quickly showcases, that while individual behaviour is relevant, structural change is necessary.

Lessons4Future – The theoretical foundation of the student laboratory

Before designing the student lab activities, we developed a framework *Lessons4Action*, that integrates theoretical evidence from the different relevant sciences.

Three main influences make up the framework: Firstly, research from physics and science education: Preconceptions about climate change (Niebert, 2010), knowledge types (Kranz et al., 2022; Roczen et al., 2013; Wynes & Nicholas, 2017) and research on students' different knowledge (Schubatzky et al., 2023) and affective predispositions (Umweltbundesamt, 2021). Secondly, environmental psychological models of linking knowledge and action (Bamberg & Möser, 2007; Hornsey et al., 2016; Kapeller & Jäger, 2020; Klöckner, 2013; Kollmuss & Agyeman, 2010) and thirdly, sociology and communication psychology on how to communicate danger and time delayed consequences (Corner A et al., 2015; Schrader & Mohn, 2022). Minor and medium inspiration stems from constructivist learning, nature of science concepts and theories on debunking fake news and disinformation. (Lewandowsky et al., 2020)

The psychological determinants of action have been integrated into the Lessons4Action framework. For this, at first, we distinguished between three kinds of knowledge, that education should convey: *Earth System Knowledge*, *Action Knowledge* and *Effectiveness Knowledge*.

System knowledge refers to the (inter)effects in the earth system, how single processes work and how they interact and mutually reinforce in feedback loops. For example, visible light from the sun is being partially absorbed by earth and converted to infrared radiation. This radiation in turn can interact with the greenhouse gases. *Action knowledge* concerns the available options for behaviour: What can be done to reduce emissions on individual and on societal level? What kind of emission occur and how can they be avoided? Heat pumps, that run on renewable energy, provide very low emission heating and warm water. *Effectiveness knowledge* then evaluates the different options based on their efficiency: Why do cheese and dairy products contribute more to greenhouse gas emission than plant-based food? Which areas of society are responsible for most emissions and which current, employable technologies pose an alternative?

Knowledge is a necessary prerequisite for action, but – and this is a scientific finding that seems to be largely ignored within the design of curricula and climate education planning – knowledge is *insufficient* to lead to action (Bamberg & Möser, 2007; Kollmuss & Agyeman, 2010; Moser & Dilling, 2012). A subset of a multitude of psychological constructs helps to link to the goal of climate action. (see Fig. 1.)

This normative goal is justified, as most countries have agreed to the 2015 Paris agreement, "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C […]" (United Nations, 2015)

Exceeding the 2°C-goal compatible emissions reduction paths calculated by IPCC is (or rather should be) prohibitive. Arguing from a human rights point of view there is also the simple argument of human dignity, of freedom and of safety of future generations: (In)Action now determines under which climatic conditions the future generations may live.

This led to our second step of literature screening, trying to conceptualize Action (Betsch et al., 2024; Kranz et al., 2022): (1) *Individual Behaviour* covers all

personal and directly induced emissions, e.g. though mobility, consumption of goods and food, but also, directed towards greenhouse gas emissions reduction, choosing to invest savings into companies that might provide environmental solutions or by installing photovoltaics on the roof. These kinds of action are salient within the perception of society and within political debate. Yet, there are two other kinds of action that might prove to be more effective:
(2) Acceptance of measures refers to the reality that there will be political decisions that change our lifestyle and the world around us – that is to avert a hothouse earth with conditions that would not permit said lifestyle in the long term anyway, of course. The mere visibility of wind turbines in the landscape or solar cells on rooftops, the increase of a carbon price, which will render all kinds of hobbies and habits (excessive meat consumption, cheap intercontinental flying) very expensive. The promise of a societal transformation towards carbon neutrality without society having to change is scientifically unattainable. (Göpel, 2016; Hagedorn et al., 2019)

(3) *Societal participation* is a potent way to act. To rally for acceptance of measures, but also to reorganize mobility (public transport), consumption (repair instead of replace), adapt and implement technologies (wind and solar power would already easily suffice to provide humankinds energetic need). Any hope of new technologies, like fusion, miraculously solving the current need for clean energy is an escapist hope, as scaling to industrial levels takes too much time to prevent the tipping points from happening. Participation can take all kinds of forms, outspoken in politic engagement in parties or as an activist, within existing structures like local clubs or associations, speaking up and explaining the necessity and implementation of measures to peers and within family.

It is obvious that these action types interact: One might "invest" the emissions of travel, to reach out and further the cause – the chain of argument the main author used to justify flying back to Germany for another upcoming conference, after travelling to the location of ESERA by train. A very important action that borders both societal participation and individual decision is prepared in school: The choice of study or non-academic specialization and then environmental attitude within employment or work. It affects which sectors find employees and if economic decisions, that take into account many variables, include efficient sustainability.

Having established knowledge as origin, and basing of climate science lessons, and action as goal, the question remains how to connect them. *Emotions* (Jonas et al., 2014; Kapeller & Jäger, 2020; Wullenkord et al., 2021) including climate anxiety and worry and their interaction with affectedness serve as strong determinants for action if they are not overwhelming and if individuals perceive behavioural control, but might otherwise lead to inhibition, inaction and tries to push away and ignore the seemingly unavoidable threat (Kapeller & Jäger, 2020). Emotions, either addressed or underlying, shape any lesson about climate change.

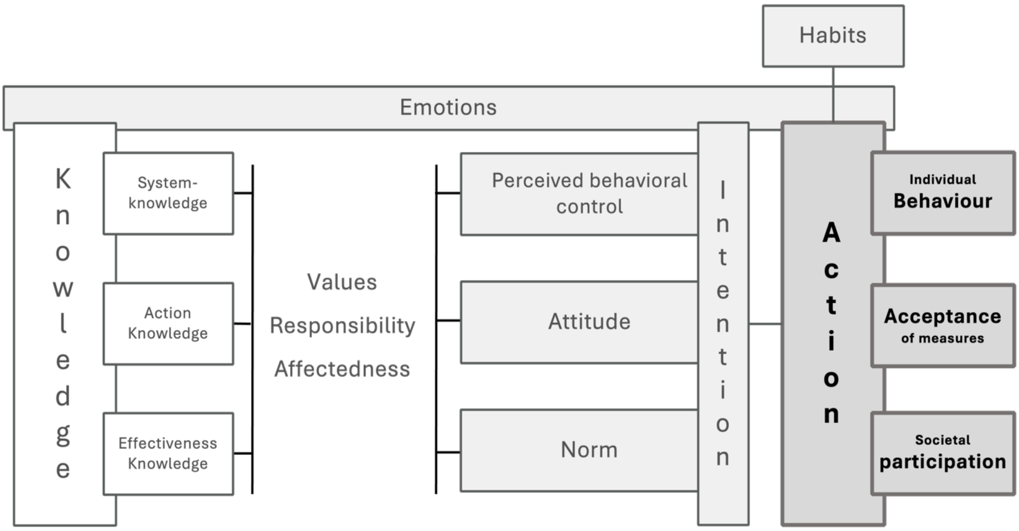
The mentioned *Perceived behavioural control*, together with *attitude* (towards climate actions) and *norms* (*descriptive*, that is what can really be observed, and *injunctive*, that is what people think is expected from them) are the tree main determinants of intentions. Addressing at least one of them within lessons about climate change might prove helpful to connect knowledge with action. (Geiger et al., 2019; Kollmuss & Agyeman, 2010).

Keeping in mind, and also discussing in class, that even an existing intention to act might not lead to action is important: Societal structures and costs (e.g. in time or money) facilitate or hinder action and might need to be changed. Another important perspective (and competency) is self-evaluating what kind of intentions are effective or mere symbolic action (avoiding plastic bags e.g. is responsible for barely any emissions, helps cutting down on microplastics though).

This is where the three kinds of action come in again: Often individual behaviour is costly and ineffective (reducing consumption, flying and heated living area being noteworthy exceptions). Structural changes are needed and furthered by the other two kinds of action: “How can you try to reduce the emissions of everybody?” (Heitfeld & Reif, 2020)

This framework addresses individual and structural change from an individualistic psychology point of view, which we think is justified, as at least the educational system of the german-speaking countries is addressing individual learners. Especially in the age group considered, just within puberty, the students evaluate and establish their self, attitudes, and values within the context of other (parents, peers, social norms). We want to stress that collective action models, e.g. SIMPEA (Fritsche et al., 2018) and the theory of social tipping points (Otto et al., 2020), are relevant perspectives on how to achieve change within society.

Figure 1. Lessons4Action Framework: Different kinds of knowledge and action and psychological variables that can be addressed in education to link knowledge with action.



Lessons4Future – evaluating the framework

A design-based research (The Design-Based Research Collective, 2003) project aims to further develop the *Lessons4Future* framework, while continuously applying and evaluating said framework in the ongoing (since April 2022) student laboratory *Labs4Future*. The first iteration was evaluated considering teacher feedback and the student's (digital) worksheet results.

In the currently running second iteration we use a more thorough mixed-methods research design. The students answer questionnaires on knowledge (Schubatzky et al., 2023), environmental attitude (Baierl et al., 2022) and climate change hope (closely resembling perceived behavioural control) (Li & Monroe, 2018) in a Pre-Post-Follow-up design. Selected by Pre-Post data results, we invite students for interviews about the laboratory and its effects on them and their class. We are interested in whether this combination of qualitative results with quantitative interviews can pinpoint new and/or confirm theoretical hypothesized mechanisms that lead to change, like e.g. the activation of social and moral norms in a peer discussion about individual greenhouse gas emissions.

Our hypothesis is that Labs4Future, while applying the framework ideas, manages to improve knowledge, environmental attitude, and perceived behavioural control. Being a learning setting that has many similarities to school lessons and other educational settings, the framework and the developed experiments and activities may prove useful to educators and teachers.

From theory to practise: An overview of the student laboratory Labs4Future

In this last section we present an overview of all central elements of Labs4Future. The first day is dedicated to the (earth) system knowledge, the second day addresses action and effectiveness knowledge. This separation is an example for the implementation of the framework: For Roczen et al. (2013) system knowledge is necessary, but insufficient for action. Only action and effectiveness knowledge directly lead to action. The first day is framed by a *Mystery* addressing heat related excess mortality in Germany (Grothaus et al., 2024). This method presents a question, that can only be explained by sorting and linking information acquired over the day within a concept map (Fig. 2):

In 2019 Yvonne and Vera caused the death of 6,900 people. However, someone else is actually responsible for their actions.

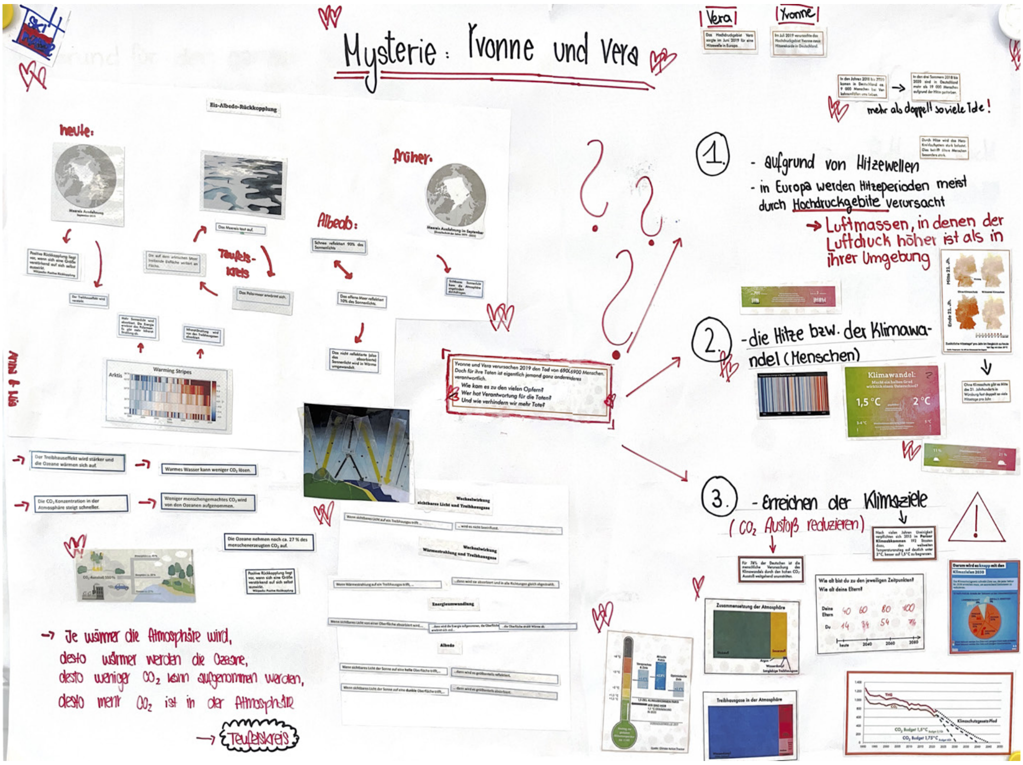
1. How did it come to the high number of casualties?
2. Who is responsible for the deaths?
3. And how do we prevent more deaths?

The three main constituents of the first day are "Weather vs. Climate", "Carbon Cycle" and "Greenhouse Effect". Each is being addressed in various new or adapted experiments (e.g. photosynthesis as a mean of reducing CO2 concentration (Gräb et al., 2021), oceans acidification and water as a carbon sink, transmissivity of infrared radiation through a greenhouse gas (Scorza et al., 2021). Upon finishing an experiment, the students prepare first concept maps as partial solutions to the mystery, explaining the phenomena (greenhouse effect) or how a positive feedback loop leads to tipping points (ice-albedo feedback, temperature dependent ocean carbon sink).

The second day starts with the students answering the mystery questions within a big concept map, integrating the partial solutions from first day plus a variety of new information snippets. (see Fig. 2. for a student solution) Yvonne and Vera were two high-pressure systems that caused heatwaves and statistically significant excess mortality in summer 2019 (Deutscher Wetterdienst, 2019a, 2019b; Robin & Ribes, 2020; Vautard et al., 2020; Winklmayr et al., 2022). Heatwaves have become and will become more frequent as global warming progresses. Forecasts of the number of heatwave days in Germany differ depending on different global warming scenarios. Who can be held responsible for this, and who should be involved in solving the problem and to what extent, is a geopolitical dilemma that is being discussed right up to the level of climate conferences.

These different responsibilities for climate action are implied by giving out slightly different information snippets for different student groups, either hinting towards the responsibility of individuals, of the Global North or of politics.

Figure 2. Student solution of the entire mystery (in German), The partial solutions of the first day are on the left, the answers to the three main questions on the right. (There is an English translation available upon request)



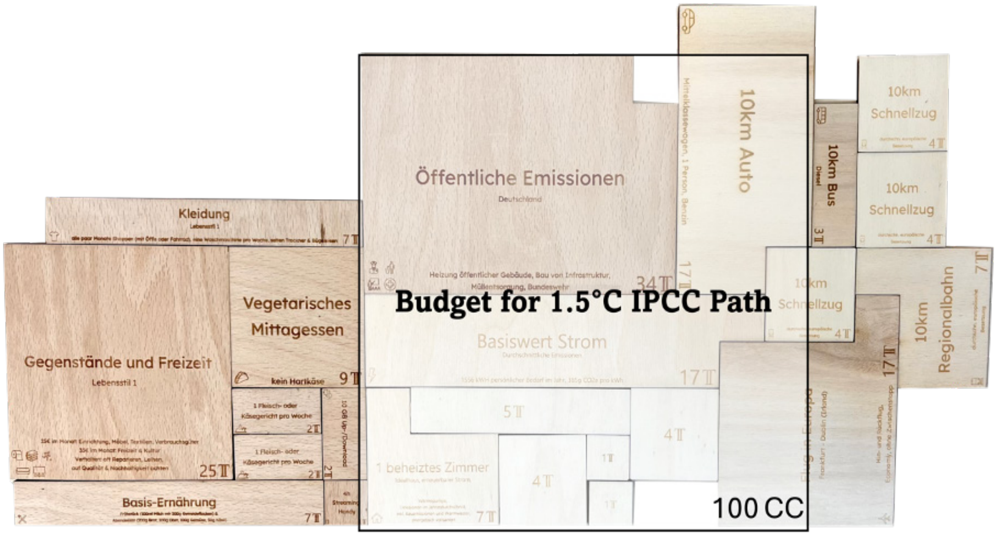
After the Mystery three one-hour activities on housing, mobility, and consumption prepare the Carbon Credits method by exploring the origins of daily greenhouse gas emissions. Alongside each activity, the students receive *Carbon Credits (CC),* area representations of the emissions of emission-relevant behaviour of an average day. One credit, a square with 2,5cm width, represents emissions of 93,4g CO_2e (that is CO_2 equivalents, a unit to make emissions of different greenhouse gases with different greenhouse warming potentials comparable). This number is deduced from a *no or limited overshoot* path to limit global warming to 1.5°C, assuming equal emissions rights for all humans on earth (IPCC et al., 2019, p. 119).

All actions and CC are designed for an average day (see Fig. 3 for a typical day). For example, 1 CC represents the amount of emissions for 1h of daily laptop streaming, taking into account charging, the grey emissions for the device and server energy need. (Suski et al., 2020)

Emissions of heating in winter or one flight per year are distributed on all days of the year, the corresponding Carbon Credit for heating or flying refers to this average (31 CC for a $20m^2$ room, with average German insulation and heating standards). Similarly, in the case of mobility, we use the preparation to calculate the daily average mobility by different means, considering single long travels e.g. for holidays.

These representations exist for most greenhouse gas relevant personal actions: From vegetarian (9 CC) or omnivorous diet (17 CC), consumption (25, 42 or 79 CC, depending on different lifestyles) to yearly intercontinental flights (100 CC for one round trip Frankfurt-Boston - that is the whole 1,5°C goal budget).

Figure 3. Average day of the first author – clearly above budget. The carbon credits are also available in English as printable PDF or laser cutter files.



These pieces of personal emissions show two aspects: Many emissions, including those through industry processes, can be traced back to personal consumption and individual decisions. Grey emissions (emissions that arise from production and recycling/disposing energy and processes) for the mere production of a car (combustible, middle class), amounts to 8095kg of carbon emission. (Teubler et al., 2018) Assuming the papers average 10.7 years of usage (this corresponds to average age of cars as of German "Kraftfahrt Bundesamt" (Kraftfahrt Bundesamt, 2024) yet is low, considering that cars continue being used after being sold abroad), this corresponds to 22 CC per day – just for being there and having used no fuel so far to really drive.

Only some climate relevant actions are open to direct individual change, while others need fundamental transformation and regulation in society and politics. Public emissions (34 CC, for heating public building up to emissions of German Bundeswehr) and average household electricity emissions (16 CC) are given factors, that cannot be changed. Heating energy, and mobility also is heavily affected by structural pre-sets. (10 km by train between Berlin and Krakow amount to 10 CC, the same distance by train via Copenhagen and Stockholm emits only 0,5 CC – relying on low carbon electricity instead of German & polish fossil fuel-based electricity mix). (Hacon, 2023)

At first, each student combines their daily emissions. Then they are confronted with the 100 CC budget. Nobody within Germanys societal conditions can currently even achieve compliant emissions.

By puzzling an imaginary, unrealistic day, only with the bare necessities of a bit of food, a single heated room etc., that is e.g. no mobility at all, even this ascetic lifestyle is at 127 CC - above the budget. Structural changes are necessary: Still having their personal lifestyle and different areas/emissions of their average day in mind, combining this with their knowledge what is important to them and their surroundings, we instruct a Utopia Thinking activity. Tasked to redesign their hometown, as a mayor with decent funding, they discuss political and structural options of change and consider how to take everybody along.

The final and take away part of the day is funnelling these recently developed ideas into a role-play-type setting: Half of the class takes exemplary roles that delay climate action (Lamb et al., 2020; Leonard Chemineau, 2024) the other half is using the learned contents to argue for their ideas, if necessary with the input of rhetorical strategies. (Schrader & Mohn, 2022, Chapter 19)

If we want to address climate change and empower the next generations to co-create solutions of a transformation of society and manage the adaption to a less stable earth system, it is vital to develop and evaluate ways on how to convey the necessity and subsequent effectiveness of actions in educational settings. We hope that the framework and the two concepts contribute to this cause.

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Analyzing Pre-Service Science Teachers' Futures Thinking

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Futures thinking is a skill that provides different competencies to those who help students cope with future events. Scenarios are future predictions created for the future by using observations from the past and present. The scenario method is one of the frequently used methods in education and allows long-term thoughts of both students and teachers to be collected. It is important to know the future thoughts of pre-service teachers who will educate future generations. In this study, a future studies perspective was used to draw attention to the long-term visions of pre-service science teachers regarding their jobs. An exploratory study was planned on pre-service teachers' images of a future work day. 50 pre-service science teachers participated in the study. At the end of the 2022-2023 fall semester, 4th grade pre-service science teachers studying at a state university in Istanbul were asked to write an article titled "my first day of work in 2040" by asking an open-ended question. The obtained data were analyzed by content analysis. Themes, categories and codes were defined. The results were given in frequency and percentages. It has been observed that they mostly wrote about the educational environments, the physical conditions of the school and the materials they will use in the lesson. Recommendations were developed based on the results. It can be said that adapting such methods in teacher education can enable pre-service teachers to form more creative thoughts about the future and create new types of projections.

Keywords: Futures thinking, pre-service science teachers, scenarios

Introduction

In the age we live in, rapid change and development greet us in every aspect of life. People who are a part of this change and development must not get lost in the process and must be individuals with "futures thinking" who can foresee the flow, dream about it and organize the changes according to their own ideals (Haapala, 2002). Futures thinking involves a structured process of inquiry into how society and its physical and cultural environment may be shaped in the future (Jones et al., 2012). Julien et al. (2018) emphasized in their study that it is possible to develop this skill starting from primary school and added the following words. *“Futures thinking competence in education, which we can define as a meta-competence, covers many skills needed for thinking about complexity, dealing with uncertainty, discussing with experts/stakeholders, making choices and therefore education for sustainable development (ESD).”* Similarly, Jones et al. (2012) said the following about futures thinking in their study:*” Investigating socio-scientific issues in science education offers an important scope for including such futures thoughts. Arguments for doing this include increasing student engagement, developing students’ values discourse, developing students’ analytical and critical thinking skills, and empowering individuals and communities to envision, value, and work toward alternative futures.”*

Scenario planning is a technique used in many fields. This technique has been used since the 1960s, starting from military applications and spreading to different areas. Scenario planning is not just about making predictions about the future and writing legends. Scenario planning is the prediction of possible futures and assumptions that may arise by using observations made today (Meng, 2009). This means that a successful scenario is deeply grounded in the reality of its current context (Burt and Van der Heijden, 2003). Scenario planning and futures thinking are also used in education. Individuals who can think about the future and create scenarios can manipulate many possible futures, regardless of which educational tool is used, and this is the aspect that allows them to improve their ability to think about the future in the long term (Julien et al., 2018).

The role of teachers who raise and educate the next generations is important in imparting the idea of the future and the skills it brings to new generations. It is important for teachers to have foresight for the future and to be able to create future scenarios, and to provide these skills to the students they educate. At the same time, futures thinking opens up possibilities to examine teachers’ long-term visions and can also be used to examine teacher agency (Varpanen et al., (2022). However, today, establishing future scenarios and creating plans is more about solving the problems we have in daily life than about the future. (Meng, 2009). Therefore, in this study, it was aimed to analyze the future ideas of pre-service science teachers who are candidates to educate the next generations. In this direction, it was ensured that they create scenarios related to the changes they think will occur in education in the future. With this purpose, the problem of the research was chosen as “What are the views of pre-service science teachers regarding the changes that will occur in education within the scope of futures thinking?”. Regarding this problem, pre-service science teachers were asked to create scenarios for future education. Then, by analyzing the scenarios created by the pre-service teachers, a general map of the pre-service teachers’ future thoughts regarding education was created and these results were interpreted.

Method

This study, is an example of qualitative research and uses a case study as a design. Case study is a research design in which a new situation with defined lines is examined by collecting data in a long-term and detailed manner (Yıldırım and Şimsek, 2016; Creswell, 2013; Merriam, 2009). Case study allows the researcher to examine in detail of a situation or event that is not under the control of the researcher. Case study is a research method that centers on the questions "why" and "how". In case studies, the research topic is finalized in a realistic and holistic manner by using various data collection tools such as observation, interview and document analysis (Miles & Huberman, 2015). This study is inspired by the work of Varpanen et al. (2022), and aimed to enable pre-service science teachers to create scenarios in order to analyze the idea of the futures in the field of future studies. Unlike their study, we did not work with teachers, but with pre-service teachers. The study by Varpanen et al. (2022) was conducted with teachers in Finland. They suggested that this practice be done in a different country. They were curious about the results of the new study.

Study group

The study group of the research was selected from a state university in Istanbul, Turkey. Purposive sampling, one of the non-random sampling types, was used to select 50 science teacher candidates to participate in the research. "Criteria sampling" was the purposeful sampling type used in the selection of teacher candidates. Criterion sampling is defined as the creation of the sample from people, events, objects or situations with determined characteristics related to the problem (Büyüköztürk, Çakmak, Akgün, Karadeniz and Demirel, 2013). The participant group in the research was determined as 4th grade university students.

Data Collection Tools

An open-ended question was asked to 50 science teacher candidates to write an essay titled "My First Day at Work in 2040". The data was collected inspired by the data collection form titled "My working day in 2040" in Finland prepared by Varpanen et.all (2022).

Data Analysis

Content analysis method was used to analyze the data. The purpose of data analysis is to interpret and extract meaning from the data. For this purpose, the researcher must interpret, reduce and clearly convey the data as they read, observes and obtains from the participants to the reader. (Çelik et al., 2020).

The articles written by teacher candidates were decisive for the themes to be used. Adhering to these themes, categories were determined in accordance with the data and codes were determined under these categories.

Each code is placed into categories and shown as a frequency value and percentage by how many participants used it. Codes that are not considered important can be deleted, if necessary, or combined with another code and grouped under a category (Cresswell, 2013). Coding and categorization were done twice by the researchers, and the same codes were combined and similar ones were removed.

Results

The analysis of the results of the interviews are shown in Table 1.

Table 1. Pre-service teachers' future thoughts about education

Themes	Categories	Code	Frequency vs Percentage
Educational environment	Workshops	Science, Design, Music, Game, Project	21 of 50 (42%)
	Different technological classroom environments	Hexagon, planet, cell, colorful	6 of 50 (12%)
	Form of Education	Online Hybrid	4 of 50 (8%)
	Practices	Projects and competitions	16 of 50 (32%)
Physical conditions of the school	Building features	Glass Concrete Garden	5 of 50 (10%)
	Social areas	Buffet Social activity	2 of 50 (4%)
	Officials	Robots Artificial intelligence applications	10 of 50 (20%)

Course materials	Course equipment and technological applications	Smart tablet	20 of 50 (40%)
		Virtual reality	21 of 50 (42%)
		3D	11 of 50 (22%)
		Hologram	6 of 50 (12%)
		Metaverse	1 of 50 (2%)
Transportation	Vehicle technologies	Flying vehicles Vehicles powered by renewable energy Teleportation Maglev trains	9 of 50 (18%)

Pre-service science teachers had opinions about the education-teaching environment in their futures thinking. These views include workshops, different technological classroom environments, education style and practices. They also mentioned the physical conditions of the schools. In their writings, they expressed building features, social areas and officials. They mentioned robots and artificial intelligence applications. In the opinions of the pre-service science teachers about the course materials, there are smart tablets, virtual reality, 3D, hologram, metaverse in course equipment and technological applications. Pre-service science teachers talked about vehicle technologies for the transportation to the school. They mentioned flying vehicles, vehicles powered by renewable energy, teleportation and maglev trains.

Conclusion and Discussion

This study is inspired by the work of Varpanen et al. (2022). As a result of this research, it was discussed whether the results of similar studies conducted in different contexts would be consistent. Our study is an answer to this debate. Our study was conducted in a different country than the previous study. This country has a different education system, but the data obtained are highly similar. It will provide a supportive contribution to the literature to support these previous studies.

In this study, it was seen that the pre-service science teachers had some imaginary images of the schools and the teaching environments. For example, %12 of the pre-service science teachers mentioned colorful differently shaped classrooms in which the students can travel in a cell or a planet in three dimensions. They mentioned digital education tools which will be used by making use of smart tablets, virtual reality, 3D and hologram. These are not much imaginary or utopian. But one pre-service science teacher mentioned metaverse which can be classified as imaginary. It has been observed that while some of them adopt the schools as they are now, some of them talk about the fact that education does not have to be in schools as it is today. It can be online or hybrid. Regarding the classroom environments, they said that the classes were created according to the type of course, not according to age groups. In the study, it was seen that the pre-service teachers had opinions on transportation technologies. The pre-service teachers said that they think that transportation will be provided by renewable environmentally friendly vehicles. These results are similar to the results reached by Rasa and Laherto (2022). Teleportation also appears as a utopian element here. In general, we can say that we reached some data that the future could be perceived as different than the present. In their study, Varpanen et al. (2022), in their study with the in-service teachers, did not find any remarkable data that the future could be perceived as better than the present in any sense. At the end of their study, no imaginary or utopian images of the future were found. We found some imaginary and utopian data in our study. This can be because we did this with pre-service teachers who are younger than in-service teachers. Varpanen et al. (2022) pointed out that in order to encourage the emergence of such utopian futures, the scenarios about the future can be used for pedagogical purposes as well as for teacher training. It can be said that such future studies have pedagogical value in their own right. In parallel with Varpanen et al. (2022), it can be said that adapting such methods in teacher education can facilitate the creation of new types of projections.

Similar results were found in other studies in the field of futures thinking. Otrel-Cass et al. (2009) surveyed 252 secondary school students in New Zealand regarding their futures environment to determine their opinions. According to the findings, 79% of the participants believe that technology will influence their futures. In this study, differently from our study, participants acknowledge that effects of technology will be both beneficial and detrimental. Likewise, Rasa et al. (2022) designed a science course that incorporated quantum computing as a preparation for the futures and proposed technical solutions to global issues. Secondary school pupils attended this course. Upon evaluation of the views of the students, it emerged that their perception of technological advancements was affirmative and that they were more inclined towards undertaking initiatives, inspired by the concept of the futures.

Briefly, it can be said that the data of these two studies, which are this study and Varpanen et al. (2022)'s study, were supportive of each other. Furthermore, there are similar results in other researches. If the study is carried out again, pre-service science teachers are recommended to draw as well as write their future thoughts. Additionally, it is recommended to ask prospective teachers a specific question instead of a general question for the future (My laboratory/science class/my students in 2040).

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Integrating Climate Change in Secondary School Science Instruction: The Case of Spain

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This paper reports on a qualitative investigation aiming to bridging the gap between climate change education policy and practice in Spain. Although recent reforms stress the importance of formal education in shifting towards a more climate friendly economy, climate change is only anecdotally represented in Spanish educational policy, which makes it difficult for teachers to integrate it in their practice. On this basis, two parallel focus groups were carried out with 29 experts, researchers and practitioners interested in climate change education, aiming to 1) Analyse current educational policies and practices regarding the teaching of climate change in secondary education in Spain, 2) Exchange views on teacher training and support in relation to climate change; and 3) Discuss the teaching of climate change in the science classroom. Results showed that climate change education is not sufficiently developed in the Spanish curriculum, but teachers have a degree of freedom that would allow them to introduce climate issues without major obstacles. Further, climate issues to bring to class were identified, including forest fires and different aspects of the food supply chain. The most appropriate methods to teach climate change issues in secondary school were found to be Inquiry-Based Learning and Project-Based learning. These results contribute to clarifying how climate education should unfold in this specific sociocultural context, providing access points to policy makers, curriculum developers or teacher training providers, among others.

Keywords: Climate Change Education, Professional Development, online learning

Introduction

In the current climate crisis, and following the recommendations of UNESCO's Sustainable Development Goals (United Nations, 2017), it is primordial that formal science education contributes to equipping students with the competences to become climate committed citizens. In Spain, recent legislation recognises the important role of secondary education in achieving a more climate-friendly economy. However, many important questions still need to be developed in educational policy in order to make climate change education a reality in science instruction, including the curriculum, teacher education or assessment standards.

In order to inform policy makers who could possibly take high-impact actions in this regard, the present study aims to contribute to conceptualising aspects in educational policy that are important for the development of educational policy, namely the curriculum and how to address climate issues in class. To that goal, a bottom-up approach was followed, which consisted of a consultation to science education experts and practitioners via focus groups. On this basis, recommendations can be made for policy makers in Spain or countries in a similar situation.

Method

The study follows the model of evidence-based policy, which states that policy recommendations come as a result of research based on the scientific method, so to develop knowledge from practice (Pawson, 2006). On this basis, a qualitative study was designed, since the focus is understanding the topic as set in this specific sociocultural context, rather than identify trends or relations between variables (Creswell, 2012). More specifically, two focus groups took place. The goals of the focus group were: 1) Analyse current educational policies and practices regarding the teaching of climate change in secondary education, 2) Exchange views on teacher training and support in relation to climate change; and 3) Discuss the teaching of climate change in the science classroom.

Participants

The first step was to select specific people that were considered key, including in service teachers, school managers, education researchers and staff from centres of training for in service science teachers. These key stakeholders were invited through personalized emails. Moreover, the invitation was sent to the mailing list of a previous European project mainly composed by in service secondary school STEM teachers from all over Spain. From this perspective, convenience sampling was used. A total of 29 participants took place in this study, i.e. 14 on the first focus group and 15 on the second. All participants were Spanish, and they all belonged to one of the following profiles: in-service teacher, member of environmental organisation, non-formal education provider, and ministry of Education representative.

Focus Group Development

Focus group 1 took place on Wednesday, 9th of November, 2022 at 17:00 (5PM), whereas focus group 2 took place on Friday, 11th of November, 2022, at 17:00 (5PM), both in virtual format. The sessions were recorded with the consent of all participants. Both focus groups followed a collaborative approach, mainly based on activities in which all participants were active by taking part in debates or performing tasks in small groups, in cooperation with others. Most of the tasks that participants performed were based on the design thinking methodology

(Panke, 2019). To that goal, the functionality “Split groups” of Zoom was used when needed.

Data Analysis

Two researchers (one senior and one postdoc) analysed the data following the content analysis method (Libarkin & Kurdziel, 2002; Lincoln & Guba, 1985). They read through the transcription of the focus groups and they identified patterns that emerged, guided by the objectives of this research. These patterns were coded using the themes that came as a result of a previous work they developed consisting of a desk research regarding the status of climate change education in Spain. Each researcher did several iterations of data analysis until data saturation was reached, and then they shared the results, to produce a final version.

Results

Integration of Climate Change Education in the Curriculum

As a result of the study it was confirmed that climate change education is not sufficiently developed in the Spanish curriculum, which makes it difficult that teachers implement it in class. Participants agreed that there are some mentions to this phenomenon and to other issues related to it (energy, natural disasters) in the science curriculum, but they are isolated and receive way less importance than other, more established content such as the facts and principles of science.

Secondly, the key message regarding the integration of Climate Change in the curriculum was that it should be included through specific contents. These contents would be distributed across the subjects in secondary school, thus refusing the idea of having a dedicated, new course on Climate Change. The contents on Climate Change could be covered in STEM subjects but also in others, since the participants consider that Climate Change education should be transversal and interdisciplinary. The contents would be specific, meaning that new contents would need to be created and added into the curriculum. Most of the content that participants suggest is conceptual, including climate change as such, but also: environmental education, health, climate justice, and social inequalities associated to Climate Change such as climate migration. Additionally, skills but mostly attitudes are mentioned as key contents of Climate Change education, such as critical thinking.

Participants also emphasized that the curricular integration of Climate Change education in secondary school must include specific mention to how it is to be taught. According to them, a big obstacle to the integration of Climate Change education in the curriculum is the content-based science curriculum, because it is contrary to the concept of Climate Change competence. Participants believe that Climate Change education should be achieved through meaningful learning experiences, where students are in the center of the learning process. To that goal, they suggest that the curriculum mentions these approaches and / or provides resources for teachers on how to apply them.

It was also noted that Spanish teachers have a high degree of freedom to elaborate their yearly programme and lessons. School managers and principals also have flexibility to organise the teaching schedule. This freedom is an opportunity for at least the teachers who are most concerned with climate change education can address this topic in class, in a transversal way if they want, by collaborating with other teachers.

Addressing Climate Issues in Class

Participants agreed about a few climate issues that must urgently be included in science instruction. The first topic is forest fires. Participants consider that it is a relevant topic for students to the extent that it affects their lives, for example when it is banned to visit natural parks because of the risk of fire. They also argued about the potential of this topic because it is a local problem (in Spain) but also global, because of recent fires in other European countries and beyond. The second, most popular topic was related to our food supply chain. Under this topic, different themes were mentioned, including the industrial model of cattle raising, the transport of foods, and the possibility for students to become actively involved in the production of the food they consume. Another topic is the rise of temperatures. Participants related this topic to the melting of the Permafrost, the increase of CO2 and the greenhouse effect gas. Participants believe that it is possible to teach these topics, arguing that the Spanish law LOMLOE – Article 110 gives what they consider as sufficient autonomy to schools to teach the curriculum in the way that they consider.

Participants emphasized that these topics should be addressed with active methodologies that put learners in the center of the learning experience, where they use digital resources to manage the information they collect and communicate the results of their inquiry to their peers, other schools, or their families. They agreed that project-based learning and inquiry-based learning are the most suitable teaching approaches. They also mentioned “Service learning”, or “ApS” in Spanish, which involves students in addressing a challenge in a real institution, by taking the role of the professionals that participate in it. In fact, a key message extracted from the focus groups was that it is essential that Climate Change education takes place in collaboration with other organisations, ideally environmental associations that are tackling one or more climate problems. In this way, the applied dimension of Climate Change education, i.e. learning about current problems that we can do something about, is emphasised. Two teachers reported having carried out projects in this direction, one of them related to the preservation of a river in the town. For these types of projects, students usually work in groups and with help of digital tools. They also use resources such as videos or readings.

More specifically, some participants considered that teaching about climate in the context of localised issues that provoke social tension or controversy is the most effective strategy. For example if most of the parents of one school worked in companies that directly or indirectly contribute to climate change, this topic could be addressed in class. They also consider as useful the collaboration between the school and non-formal education institutions.

Teacher education for climate change education

Regarding teacher education for teaching climate change issues, participants agree that this should be an essential aspect of initial and continuing teacher education. Teachers should be trained about the facts and principles of climate change but through an emotional approach, which they describe as "knowledge for loving and for protecting (nature)". Participants reject a theoretical training, but promote a practical approach through practical examples or current problems. In their opinion, teachers should learn about Climate Change through active methodologies and they should do so as part of a network that includes other teachers and climate organisations such as research institutes and NGOs.

Participants expressed that in terms of Professional Development (PD), teachers like to hear about best practices that inspire them, and that they can adapt to the specific context of their school. If this exchange can be accompanied by dialogue with the author/s of the best practice/s, that's even better. In their opinion, as part of this model reflection about the implementation of these best practices in the classroom is essential to avoid that teachers do it as a one-off activity or they get discouraged. In their opinion, any training on Climate Change education should be in an online format because it is more likely that they complete it as they do not have to travel to a specific place. Online training should also allow some flexibility in terms of schedule, because not all teachers are available at the same time. In this sense, a module-based course is more attractive than a synchronous course with scheduled online meetings. Some participants in the workshop believe that even if the online format is more flexible and more teachers can be reached, the possibility to hold face-to-face meetings should be open, as a way for teachers to stay motivated and interact in a more informal way. Several participants expressed criticism about available training programmes and resources for teachers that are sponsored by companies that in fact contribute to climate change, such as energy companies. The training should be recognised with certification.

Discussion and Conclusions

To sum up, the study confirmed that participants are interested in climate change education, they think it is very necessary and support its inclusion in the curriculum, not just for science or STEM subjects but in a transversal way. This outcome can be interpreted considering that the Spanish government calls regional governments to set up training initiatives for all teachers in the next 3 years, has invested in a plan for sustainable development education and devoted resources to fund initiatives and organisations so that they develop resources and activities relevant for climate change education. This is to say, participants may have been exposed, aware or taking part in one or more of these initiatives. These initiatives, however, are not very coordinated and depend on individual teachers' interest. For this reason, more support at an institutional level is needed. A few of the topics that emerged as ideas to bring climate change into the classroom come from news that were relevant at the moment of carrying out the focus groups. This leads to thinking that when designing educational materials about climate change, teachers will be inclined to address current topics more so than those with only scientific value. In this sense, the climate issues that emerged as priority can be interpreted as Socioscientific Issues, which are socially relevant issues, often controversial, with a link to scientific principles (Troy D. Sadler, 2011; Zeidler, Herman, & Sadler, 2019). This could be due to the profile of the participants, where the diversity of profiles may have led to refined ideas that incorporate several perspectives on the climate issues. As per the teaching methods, the most intuitive are inquiry-based learning, project based learning and in general, any method that puts students in the center of their learning process. In Spain, teachers are familiar with these methodologies, therefore it should be an advantage.

Last, the importance of teacher education for climate change education to become a reality was emphasized. Such training should be flexible in terms of schedule and practical, i.e. focussed on best practices, and support interaction between participants and reflection. In this regard, the quality standards are set high for any institution planning to offer training in this matter. In Spain, teachers seem to be looking for quality rather than quantity of training. This could be due to the wide offer of in-service teacher training and the little time that teachers have in this country.

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Sustainability of Aviation and Space Subject Area in Science Education

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The aim is to elaborate on the concepts of aviation and space in the education of K12 level students, and to present thoughts and suggestions to train the workforce needed by the national aviation and space industry. The development of education and teaching processes in this field is also researched while examining the aviation and space studies of countries, and what needs to be done in Turkey's aviation and space policies and educational practices is explored. In this study, the main aviation and space education and teaching practices around the world are examined and compared with the efforts in Turkey. The document analysis method, one of the qualitative research methods, was used in the study. In this study, the approaches of countries providing aviation and space education at the K12 level in the near future, and the current situation for understanding the importance of the subject in Turkey, were examined using purposive sampling methods, including easily accessible situation sampling. The choice of this method is based on the idea of bringing speed and practicality to the research. It was determined that when the general approach of the United States, Canada, the United Kingdom, and Australia to this field and their studies are examined, Turkey has relatively lagged behind in its efforts in this area.

Keywords: Science education, aviation, space

Introduction

"The most effective weapon and vehicle of the future is undoubtedly airplanes. One day, mankind will walk in the skies without airplanes, go to other planets, and perhaps send us messages from the moon. There is no need to wait for 2000 years for this miracle to happen. Developing technology is already heralding this to us. Our duty is to ensure that we do not fall too far behind in this regard." These words were spoken by Mustafa Kemal Atatürk during his visit to the Eskişehir Air Regiment in 1936, and they are an indication of how well and foresightfully the future goals were selected in the early years of the republic. Looking at the recent past, when the Turkish Science and Technology Policy used between 1993 and 2003 is examined, it is seen that aviation and space technologies were defined as one of the most important elements of the 2023 Turkey vision in the Vision 2023 strategy document that shapes science and technology policies in Turkey. Many countries joined the space studies that the USA and the USSR started in the 20th century, and joint studies have even started today. The increase in activities in space, the necessity and the emergence of related problems have led to the need for a specific law and policy in this field, and to the training of a workforce for work in this area.

While the aviation world has stepped into a new era defined as lower-cost, cleaner, safer and quieter air travel, the need for space research, especially satellite use and space-based information technologies, for nations that want to increase their competitiveness is increasing day by day. The most important way to meet this need will be to increase support for research and technology development. The European Community, European Space Agency - ESA and other space agencies support the effective investments needed by the aviation and space industry. In the thematic field of Aeronautics and Space of the European Union 6th Framework Program (6FP), strengthening and consolidating Research and Technological Development (RTD) efforts and achieving high level technological excellence, in line with The Advisory Council for Aeronautics Research in Europe - ACARE and European Space Strategies. Considering the development of air transportation as well as the negative consequences it may bring, the European Union has included research activities related to environmental protection, aircraft navigation safety and the development of more durable materials within the scope of 6FP. Although aviation and space activities are classified in different thematic areas within the 7th Framework Program (7FP), the change in targets, especially in the field of space, attracts attention. While the targets in the field of space within the scope of 6FP are roughly on the development of satellite systems, in the 7FP they have become remarkable in the form of space-based applications in the service of the European community, space exploration and research and technology development to strengthen space organizations (Koru & Özalp, 2005).

Method

In this study, the main aviation and space education and teaching practices around the world are examined and compared with the efforts in Turkey. The aim is to elaborate on the concepts of aviation and space in the education of K12 level students, and to present thoughts and suggestions to train the workforce needed by the national aviation and space industry. The development of education and teaching processes in this field is also researched while examining the aviation and space studies of countries, and what needs to be done in Turkey's aviation and space policies and educational practices is explored. The document analysis method, one of the qualitative research methods, was used in the study. The approaches of countries providing aviation and space education at the K12 level in the near future, and the current situation for understanding the importance of the subject in Turkey, were examined using purposive sampling methods, including easily accessible situation sampling. The choice of this method is based on the idea of bringing speed and practicality to the research. The general approach and studies of the United States of America, Canada, England and Australia are examined.

Results

Since education systems vary greatly from country to country and can change over time, it would be difficult to create a comprehensive list of all countries that include aviation and space topics in their K12 curricula. Therefore, examples of the main countries that include aviation and space topics in their K12 curricula are given in general terms.It was determined that when the general approach of the United States, Canada, the United Kingdom, and Australia to this field and their studies are examined, Turkey has relatively lagged behind in its efforts in this area.

When the example of the United States (US) is examined, aviation and space education is generally included in science classes and sometimes in social studies or history classes. The science education standard called The Next Generation Science Standards (NGSS), adopted by many states in the US, forms the framework. NGSS focuses on space exploration and engineering design. For example, in 5th grade, students are expected to develop an understanding of the characteristics of the solar system and the universe, while in 8th grade, students are expected to develop an understanding of the role of gravity in the solar system and beyond. In high school, students may have the opportunity to take special classes in subjects such as astronomy, astrophysics, or aerospace engineering.

In Canada, aviation and space education is generally included in science classes, but can also be included in technology education or social studies classes. For example, in the Ontario curriculum, which is applied in one of Canada's most populous provinces, aviation and space are covered in both 6th and 9th grade science classes. In 6th grade, students learn about the characteristics of the solar system and planets, while in 9th grade, they learn about flight principles and aviation history. The curriculum also focuses on careers in the aviation and space fields.

In the UK National Curriculum, which is valid for primary and secondary schools in England, the subject of aviation and space is included in the Basic Stage 2 (7-11 years) and Basic Stage 3 (11-14 years) science curriculum. In the UK, aviation and space education is included in science classes, but may also be included in geography or history classes. In Basic Phase 2, students learn about the Earth and the solar system, including the phases of the moon and the orbits of the planets. In Basic Stage 3, students learn the history of astronomy and the electromagnetic spectrum. The curriculum also includes opportunities for students to engage in practical space-related activities such as designing and testing rockets.

The subject of aerospace is included in the Australian Science Curriculum in primary and secondary schools across Australia. In Australia, aerospace education is often included in science classes, but may also be included in technology education or social studies classes. In primary school, students learn about the Earth and its place in the solar system, while in secondary school, they learn about the structure and formation of the universe, the properties of stars and galaxies, and the technology used in space exploration. The curriculum also focuses on the history of space exploration and its impact on society.

Conclusion and Recommendations

These curricula in aeronautics and space aim to develop students' understanding of the physics, engineering, and astronomy principles associated with space exploration, and their understanding of the cultural and historical significance of space exploration. It also provides opportunities for students to develop scientific inquiry skills such as designing and conducting experiments, analyzing data, and communicating scientific ideas. Educating children about aerospace is important because it can inspire critical thinking, creativity, global citizenship, and environmental awareness while also inspiring them to explore new ideas and pursue careers in STEM. This study, which reveals the place and importance of Aviation and Space in the future, and which is carried out by examining the examples of education and training programs in the world at the K12 level, reveals the necessity of including it in education programs in Turkey in the light of studies in the field of Aviation and Space. Again, the reflection of the studies in this field to vocational high schools will contribute to raising individuals who are suitable for the STEM approach by gaining good technical skills, considering that the training given at this level is aimed at gaining professions and training technicians for the production sector.Besides, it is important for countries to educate students about aeronautics and space for a few more reasons: Educating children about aviation and space can increase their curiosity and interest in science, technology, engineering and mathematics (STEM). Children who are introduced to these fields at an early age will be more likely to pursue a career in these fields in their future lives, as desired.

Learning about aviation and space requires children to think critically and solve problems. These skills are essential in every aspect of life and can be developed through activities such as designing and building model airplanes, studying the principles of flight, and exploring the mysteries of space.

Aviation and space exploration are fields that require a lot of creativity and innovation. By learning these areas, children can develop their creativity by designing new aircraft or spacecraft, exploring new ideas, and pushing the boundaries of what is possible.

Since the field of aviation and space contains less scientific information than other science subjects and the experimental studies that can be done are limited, the rate of students using their imagination is higher than other subjects. In this way, the child can produce ideas more freely in a social sense, because the scientific knowledge that can claim the contrary is still limited. More scientific knowledge in other science subjects limits imagination and may cause ridicule in the classroom, especially in middle school students, as its antithesis can be created.

Learning about aviation and space can also help children develop a sense of global citizenship. By studying the history and achievements of aeronautics and space exploration, children can gain a greater appreciation for the diversity and interconnectedness of principles, developing a perspective that science is actually the product of collaboration between countries.

Aviation and space exploration also has an impact on the environment. By educating children about these areas, they can be encouraged to consider the environmental impacts of aviation and space activities and explore ways to reduce this impact. Again, studies can be done on the sustainability of space, one of the fresh agendas.

The importance Turkey attaches to aviation and space is increasing day by day. Within the scope of the National Space Program announced in 2021, the "first manned space mission" was successfully implemented with Turkey's first astronaut Alper Gezeravcı making a space trip to the ISS on January 19, 2024. The Minister of Industry and Technology of Turkey emphasized that projects such as the National Technology Move program, space science mission and Türksat 6A are among the priority plans for 2024, and that he has to ensure that design and production studies are carried out in the country.

Although Turkey is later than other countries, it has shown the importance it attaches to this field with its investments by sending its first astronaut into space. The Minister's statements stated that R&D expenditures have increased to 12 billion dollars annually, that they have provided 5.1 billion liras of support to more than 7,500 projects of 180 universities and 2,600 companies through TUBITAK, and that they have continued their technology development journey with 9,951 startups in 101 technoparks established in 60 cities. He pointed out that they have established an infrastructure with 1623 R&D and design centers. He also stated that they will continue to support green transformation (. These stated goals will also bring about some updates in educational goals.

According to the statement made by the Ministry of National Education, the new curriculum, which is being prepared for all education levels from pre-school to senior high school, will be gradually implemented starting from "pre-school, primary school first, secondary school fifth and high school ninth grade" in the 2024-2025 academic year. The Ministry of National Education is making a new curriculum change that targets the "holistic education" approach, which is based on the versatile development of students in terms of mental, social, emotional, physical and moral aspects (MEB,2023). During the creation or revision of curricula, the contents of countries that have previously worked on this subject should be examined.

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Strand 10

Environment, Health and Science Education

Albert Zeyer & Suzanne Kapellari

Strand Chairs/Co-editors

Foreword

The chapter titled Environment, Health, and Science Education in the ESERA 2023 proceedings addresses the critical intersections between science education and the well-being of both our planet and its inhabitants. In a world grappling with environmental degradation, public health challenges, and the growing complexity of scientific issues, education plays a pivotal role in preparing individuals to understand and respond to these intertwined concerns.

The 8 proceedings presented in this chapter offer diverse perspectives and research findings that explore how education can better equip learners to navigate the complexities of environmental and health-related issues. These contributions investigate pedagogical approaches, curriculum design, and educational practices that promote awareness, knowledge, and action for both environmental stewardship and public health.

This chapter showcases innovative studies that emphasize the connections between environmental and health education, highlighting how integrated science education can empower students to engage with real-world problems. Whether through fostering critical thinking about environmental impacts or understanding the links between health and sustainability, these proceedings illustrate how science education can be a powerful tool for building a healthier and more sustainable future.

As you explore the insights and research presented in this chapter, we hope you find inspiration in the ways education can bridge knowledge and action, ultimately contributing to a better understanding of our shared environmental and health challenges. The work compiled here reflects the dedication of educators and researchers committed to advancing science education that not only informs but also inspires meaningful engagement in the issues that shape our world.

Identification of Native Animals and Willingness to Protect them by Primary School Students

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Biodiversity education can be a lever of action to respond to the global crisis of biodiversity loss. In this work, we assess future generation's knowledge about native species and willingness to protect them. To this aim, we showed 6 to 12 years old children (n=1975) from northern Spain ten color photos of different autochthonous animals from different taxa, including a common and a threatened species. Afterwards, we asked them to write down the animals' name and to select five of them to be protected. Results reveal that native species' knowledge is low, although it increases with age. In addition, children preferences to protect animals seem to be influenced by emotions, and not solely by their identification accuracy or by conservation priorities (e.g., species with a threatened status). These findings point out the need to provide children the appropriate training addressing the species' features to be taken into account in order to ensure their preservation.

Keywords: Biodiversity Education, Species identification, Conservation preferences

Introduction

Together with climate change, biodiversity loss is one of the main issues of the current global crisis. People's responses to the loss of biodiversity and their support for conservation initiatives will rely, largely, on their biodiversity literacy, which involves biodiversity knowledge and relevant behaviors that contribute to its preservation (Moss et al., 2014). One of the most assessed biodiversity literacy scales among citizens is species literacy, which can be evaluated employing broad methods such as identification or listing, or in-depth questions about the origin, habitat, diet, or behavior of the species (Hooykaas et al., 2022). Latest research works assessing broad species literacy suggest that citizens from westernized countries have little knowledge about local fauna (e.g., Barrutia et al., 2022). This is worrisome, since species literacy can be linked to higher pro-environmental attitudes, including pro-conservationsts (e.g. Papageorgiou et al., 2022). Likewise, attitudes towards conservation shape individuals' preferences for specific actions, policies, and resource allocations. As saving species usually requires human mediation, and public preference should influence conservation in democratic contexts (Smith, 2011), it is imperative to identify which factors shape citizens' preferences to protect animals. Furthermore, children's opinions should also be taken into account in conservation campaigns as they can be natural change agents and actively take part in decision-making processes from early years (e.g. Chawla & Cushing 2007).

Recent works suggest that children's reasons for protecting a species can vary greatly, and several aspects come into play, such as species' aesthetic characteristics, their profitability or their salience in media (Panisi et al., 2022; Rosalino et al., 2017; Shapiro et al., 2016). Hence, considering that children will have to face individual as well as political decision-making processes about biodiversity issues both at present and in the future, it is key to assess their conservation preferences, and the factors shaping them, in order to design proper educational interventions in the field of biodiversity education. Moreover, attitudes and behavior toward the environment start developing at the early age of seven, increase until the age of ten, and afterwards level off and decrease (Otto et al., 2019). Hence, promoting positive attitudes during childhood is more feasible than during adulthood, when attitudes and behavior are consolidated. Interestingly, a similar trend has been observed for species identification skills, which are powerful during childhood and tend to reach a peak or even decrease during puberty (Huxham et al., 2006).

Research Questions

Taking into account the aforementioned, the current study aims to respond to the following research questions:

- RQ1: Which is 6 to 12 years-old children's knowledge about native animals? Does it change with age?
- RQ2: Which autochthonous animal species are they most willing to protect? What can influence that?

Methods and Context

The study was conducted in the Basque Country, northern Spain, where nowadays there are more than 150 animal species listed in the catalogue of threatened species. Participants included 1975 students attending Primary Education (PE) in 52 different schools. They were enrolled in all the 6 different levels of PE in Spain: PE1 (6/7 years old, n=164); PE2 (7/8 years old, n=340); PE3 (8/9 years old, n=545); PE4 (9/10 years old, n=245); PE5 (10/11 years old, n=447); PE6 (11/12 years old, n=234).

Students were provided an A4 size paper composed by two parts. In the first one, 10 color photographs of native wild animals from different taxa appeared, and children were asked to write down which animal they thought it was. Similar tests have been used recently to assess species literacy (Almeida et al., 2018). Species were selected with the help of a zoologist who is a full professor at the University of the Basque Country. We selected pictures of adults and made sure that they displayed species-specific morphological characteristics. All species were occurring in the area students lived and birds were breeders/residents in the area. Photographs included 2 animals of each of the following taxa: mammals, birds, reptiles, amphibians and invertebrates. First species of each group was a non-threatened common species in the area, whereas the second one was a threatened native species (Basque Government 2022). In addition, the global conservation status of some of the latter species was of concern according to the IUCN Red List of threatened Species (version 2022-2), such as the European mink that is critically endangered globally or the European pond turtle that is considered near threatened internationally. Species appearing in the photographs can be consulted in Table 1. In the second part of the questionnaire (in the same sheet), and similar to Ballouard et al. (2011), children were asked to select 5 animals (among the ones shown) they would like to protect.

For assessing the correctness of species identification, the taxonomic closeness of mentioned animals to the corresponding species in the picture was analyzed. Hence, it was determined whether the identification was correct at species level, or to a higher taxonomic level. Afterwards, each taxonomic level match was assigned an identification score (IS) similar to Gerl et al. (2021) but with modifications. We conferred one point to a species-level match identification, and followed an exponentially decreasing pointing system at each higher taxonomic level. Thus, final taxon-match punctuation was as follows: 1 (species), 0.5 (genus), 0.25 (family), 0.125 (order), and so on.

Kruskall-Wallis non-parametric tests followed by Mann-Whitney post-hoc with Bonferroni correction were conducted in order to determine whether differences existed in the number of answers given by students from different PE levels.

Findings

RQ1: Animal Identification Scores

Children, on average, gave name to 7.6 animals from the photographs, and the amount of animals named augmented together with students' age ($p<0.001$). On average, wild boar achieved the highest identification score (IS), and the white-throated dipper and the common pill-bug the lowest (Table 1). After summing up all IS achieved by each student naming the 10 animals, we found that average knowledge of local fauna was very low (mean of 1.99 out of 10 if all animals were identified at species level). This finding is consistent with earlier results indicating that the teenagers from the region have a low level of native species knowledge (Barrutia et al. 2022; Díez et al. 2018; Pedrera et al. 2023). However, the current study shows that this phenomenon has deep roots, being already present at early elementary schooling and involving knowledge of both common and threatened native species in the region.

Table 1. Mean animal identification score (IS) and percentage of students selecting each animal for protection, displayed in descending order of protection preference.

Common name	Scientific name	Mean IS	% selected		
European mink*	*Mustela lutreola*	0.13	70.1		(2)
Fire salamander	*Salamandra salamandra*	0.26	60.2		*(7)*
Wild boar	*Sus scrofa*	0.86	50.4		*(1)*
European pond turtle*	*Emys orbicularis*	0.10	48.0		*(6)*
Great spotted woodpecker	Dendrocopos major	0.14	44.2		*(3)*
Orange-spotted emerald*	*Anax imperator*	0.07	40.9		*(10)*
Smooth snake	*Coronella austriaca*	0.15	37.2		*(5)*
White-throated dipper*	*Cinclus cinclus*	0.05	34.1		*(4)*
Common pill-bug	*Armadillidium vulgare*	0.05	31.1		*(9)*
Natterjack toad*	*Bufo bufo*	0.18	30.3		*(8)*

*: species listed in the Basque Catalogue of Threatened Species. Numbers between parentheses denote the order in which the animal appeared in the photographs.

This low awareness of native species seems to be a widespread syndrome in westernized countries (Genovart et al., 2013; Pilgrim, 2008) and can be a result of the ‘extinction of experience’ (Pyle, 1978), that is, the present disconnection of citizens from nature (Soga et al., 2016).

In any case, sum of IS increased together with students’ age ($p<0.001$), eldest students reaching an average of 2.77 score. Hence, it is clear that students’ personal experiences, formal learning or out of school activities have a positive impact on their knowledge about local fauna.

RQ2: Willingness to Protect Animals

Children's preferences for protection were not solely directed towards endangered species, and the selection of species was not directly linked to a higher mean IS (Table 1). Among the 5 species they had to choose, most students selected European mink to be protected, followed by salamander. The high preference for the mink can be explained by the fact that humans have a tendency to feel attention and affection towards animals with infantile physical features, such as large rounded forehead, or short and narrow nose (e.g., Martín-Forés et al., 2013). The preference for protecting the salamander can be the consequence of children showing a stronger willingness to protect aposematic animals over inconspicuous, cryptic ones (Prokop & Fančovičová, 2013). On the contrary, the least chosen animals were the common pill-bug and the Natterjack toad, which can be a consequence of having a discrete coloration but also because of the emotions like fear or disgust commonly aroused by these taxa (Jimenez & Lindemann-Matthies, 2015; Soga & Gaston, 2020).

Implication

The results of this study reveal that children from northern Spain have little knowledge of local fauna, although it increases and becomes taxonomically more accurate with age. However, when it comes to selecting native animals with conservationist aims, a higher knowledge solely does not explain a higher preference for protecting a species, and it seems that students' preferences are also based on other reasons, for instance on aesthetic and emotional ones. In any case, this must be further studied.

The current findings shed light on the importance of providing children the appropriate information about effective conservation priorities, such as species with declining or threatened populations, or those with large ecological or evolutionary roles. Moreover, the educational efforts aimed to raise awareness towards threatened species should also encompass the promotion of rational and affective bonds with them. Hence, there is still much work to be done.

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DIY Fluorescence Microscopy for detection of Microplastics with Secondary School Students – an Education for Sustainable Development Workshop

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Microplastic pollution and its impact on human health and the environment are topics of growing concern. However, there is a lack of affordable and accessible methods for microplastic detection, especially in secondary schools. This paper presents a workshop that incorporates a cheap and simple protocol for microplastic detection, developed specifically for secondary school students. The workshop aims to enhance students' understanding of microplastic-related environmental and health issues by making them aware of the ubiquitous pollution of the environment by microplastics, training them in the use of simplified analytical chemistry methods, and providing them with knowledge about current research in the field. The workshop was designed to address the limited prior knowledge and understanding of microplastics among secondary school students. In this article, we report results of a pre-post-survey with n = 49 secondary school students regarding their behaviour-based environmental attitudes. We show that students have limited knowledge on the topic of microplastic pollution and potential health hazards as well as the source of pollution. Furthermore, we were able to increase the perceived relevance of microplastics to the students' daily lives as shown in the survey.

Keywords: microplastics, students' knowledge on microplastics, education for sustainable development

Introduction

Microplastic (MP) pollution has gained increasing attention in both the general perception and in research (Kurniawan et al., 2021; Xu et al., 2020). For example, it is now well-known that humans ingest MP particles via their diet (Cox et al., 2019). However, there is little evidence regarding the toxicity and impact on the human health as well as the environmental implications of microplastics pollution (Prata et al., 2020; Vethaak & Legler, 2021). An additional aspect is that MPs can adsorb organic pollutants (Tourinho et al., 2019), making them more concerning for human health. Currently, there are no standardised cheap and simple methods for microplastic detection. For identification of MP particles, Infrared- and Raman-spectroscopy are widely used, often in conjunction with fluorescence microscopy. There, Nile red has been established as fluorescence dye (Shruti et al., 2022), but counting of particles is still done manually under the microscope. For undergrad university students, methods for detection in soil samples (Rowe et al., 2019) by conventional microscopy and in seawater using modified optical microscopes for fluorescence microscopy (Labbe et al., 2020) as well as in bottled water (Scircle & Cizdziel, 2020) have been published recently. There have also been citizen science projects using Nile red (Valine et al., 2020). Unfortunately, for most secondary schools the equipment used in those experiments is still not affordable. To add to that fact, learning about microplastics is hardly integrated into the Austrian secondary school curriculum or other comparable curricula. Therefore, it is hardly a surprise that most studies find that (university) students' knowledge on the topic of microplastics is extremely limited. Generally, there is a commonplace idea of what microplastics are: they are usually thought to be some kind of very small plastic particles. In addition, among university students there is a general idea that microplastics are in some way dangerous, either as health hazards for living organisms, as environmental hazards due to limited biodegradation or ingestion by animals or humans (Raab & Bogner, 2021). This limited knowledge in students seems to directly translate to a limited knowledge in consumers, where there was shown that only a very small amount of knowledge on pollution and potential health effects was found (Oleksiuk et al., 2022). This lack of knowledge is further found when asking for main sources of microplastic pollution, where packaging was wrongly attributed as the main contributor to the pollution as opposed to individual traffic (Raab & Bogner, 2021). It was also shown that a main source for information on microplastics were media and the internet, with school and education being hardly mentioned (Janoušková et al., 2020). All these findings indicate that there is a profound need of concepts for schools that provide students with learning experiences on this key topic.

Keeping in mind that most of the equipment used for microplastic detection is expensive and the analyses are time consuming, our first goal was to develop a cheap protocol that is applicable in secondary schools with a low budget. We achieved this and developed a method that is not only affordable, but also works with non-hazardous chemicals as well as easy-to-use and easy-to-handle materials (Majcen et al., 2023). In this proceedings paper, we present a workshop incorporating the methods we developed and how this workshop influences behaviour-based environmental attitudes of students. Furthermore, we wanted to look into the ideas that secondary school students have of what microplastics are and what health & environmental impacts they have.

Rationale & Aim

As mentioned before, preliminarily we aimed at developing a set of experimental methods. Here, we describe a workshop embedding these methods aiming to enhance the students' understanding of microplastic related environmental and health issues in three main ways. (1) We want students to be made aware of the ubiquitous pollution of the environment by microplastics. They are enabled to detect microplastic particles in contaminated soil and sediment samples handed to them. (2) We aim to train them in the use of (simplified) methods of analytical chemistry that are used as state-of-the-art in real-world-scenarios. We want to use current methods so they can better comprehend limitations and possibilities of current research in analytical chemistry. (3) The newly gained knowledge about the presence of microplastics in our environment and therefore in our food chain is expected to be used as a basis for discussion of toxicity and health impact of the particles found. Part of the discussion should be the urgent need of more data collection on the health impact caused by microplastics. For validation of our aim, students' perception of the experience was researched in five microplastics workshops working with three secondary schools.

Methods

Experimental

MP contaminated soil or sediment samples are handed to the students. Sieves are used to separate the particles in the sample by size. For the other fractions, floatation in a potassium carbonate solution (Gohla et al., 2021) is used to separate part of the organic matter and most sediments from MPs. The remaining particles are stained using a solution of Nile red in acetone and water for 15 min. The stained particles are analysed in a DIY low-cost fluorescence microscope built from cardboard, using UV-flashlights and monochromatic LEDs as irradiation source and coloured film or filter glasses as filters. For detection, mobile phones were used for visible particles. To reduce cost and time consumption, instead of real samples from the environment, one can prepare samples where sieving and floatation is not necessary without losing out on the fluorescence microscopy part of the experiments. A more detailed description of this method was published recently (Majcen et al., 2023).

Pre-Post-Survey

In the three-hour-workshop, students worked on various theoretical and practical aspects of the microplastic pollution. In a pre-post-treatment design, we surveyed n = 49 students in 5 students' workshops at the University of Graz. Workshop sizes ranged from 6 to 22 students, but in the lab group size was consistently 2-3 students. In the questionnaire before the intervention, we wanted to assess the students' knowledge on microplastics. An open question on the definition of microplastics was followed by knowledge questions on health hazards and microplastic sources on a five-level Likert scale. Those questions were only asked before the workshop. Both pre- and post-workshop we asked students nine questions on behaviour-based environmental attitudes developed for adolescents (Kaiser et al., 2007) as well as for the relevance of microplastics in their daily lives. After the workshop, we additionally added a range of evaluation questions on the workshop.

Development of a 3-hour Student-Workshop

In this section, we want to present the ideas and research that was used for the development of the workshop as well as its contents and structure. For this workshop, backed by the research showing the generally low knowledge levels about microplastic in students, we wanted to combine a profound theoretical introduction with our aim to generate an experience that provides experimental insights. Therefore, as presented below in Table 1 the workshop was designed as described in the following. First, we introduced the students into the topic by discussing a definition of microplastics, differences between primary and secondary microplastics and main pollution sources to address the most common knowledge gaps (Raab & Bogner, 2021). Then, we presented common steps of analytical processes and how they are implemented in sediment analysis, highlighting the relevant steps for further lab work (sieving & density staining as sample preparation; staining for identification).

Table 1. Contents of the first part of the workshop.

Time needed	Content
10 min	Welcome, introduction and pre-survey
30 min	Theoretical Introduction definition and characteristics of (micro)plastic introduction of state-of-the-art analysis methods discussion of experiments (density separation and staining)
50 min	Lab Work Part I sieving and density separation filtration and staining

After this introductory input, lab work was carried out and students worked on a sediment sample provided to them. In general, the steps of the analysis are easy to handle, and students usually only need limited support with some steps. When the sample is prepared and students leave it in the staining solution, there is a wait time that can be perfectly used for a group discussion (see Table 2) addressing environmental and health issues related to microplastic emission. We found it most interesting to address the ubiquity of microplastic pollution ranging from deep sea (Van Cauwenberghe et al., 2013) to remote mountain lakes (Free et al., 2014). Because of this fact, students usually easily accept that microplastic particles can be ingested via the food chain and therefore found in humans (Jenner et al., 2022; Leslie et al., 2022). This is especially concerning to the students because recent research already shows a level of cytotoxicity and influence on the human cell (Danopoulos et al., 2022). However, this discussion part is open to be altered by the educator – our proposed focus fits into the context of education for sustainable development, but another focus might be more relevant depending on context. After this discussion phase, the second part of lab work is carried out, focussing on the fluorescence detection using our low-cost setup. In a conclusive discussion, the students reflected on their findings and learnings, usually supported by the fact that they found microplastic in real-world sediment samples during lab work.

Table 2. Contents of the second part of the workshop.

Time needed	Content
30 min	Discussion impact of microplastics on the environment impact of microplastics on human health
40 min	Lab Work Part II fluorescence detection using the low-cost microscope
20 min	Conclusive Discussion discussion and reflection of learnings post-survey

For further information on the evaluation of the workshop, please refer to our publication describing the practical part (Majcen et al., 2023).

Results and Discussion

In this chapter, we will present the results found in the survey, in particular the initial part on previous knowledge about microplastics and their health and environmental implications. For us, it was of particular interest to investigate what exactly students think microplastics are and what they associate with the term. Therefore, our first question was open-ended, asking the students to please define the term microplastic. As we mentioned before, it is known that there is a commonplace idea that microplastics are very small plastic particles of some kind. We investigated the students' definitions and found that this is the most common definition among students as well. While only a small portion of the students indicated that they had no idea what microplastics were, and another few students defined microplastics differently, a majority of nearly 9 out of 10 of the students defined microplastics as "(very) small plastic particles", with a varying degree of additional information. Of these definitions, about one third added no more context to the definition. Of the remaining two thirds of the answers, the added context is highly interesting and reflective of the students views on the topic. The most common pieces of added information were that the plastic particles are "microscopically small / not recognizable with bare eyes" (stated in 60 % of the overall definitions), "found everywhere in our environment" (20 % of overall definitions), "(extremely) harmful for humans and the environment)" (10 % of overall definitions). It is of particular interest that a majority of students include in their definition the statement that microplastics cannot be seen with bare eyes, when in reality all plastic particles below 5 mm are classified as microplastics. Some further remarks were that microplastics "originate from the degradation process of bigger pieces of plastic". Other than the microscopic size, there were a few mentions of sizes with answers ranging from "particles below a 1 mm size" to a more informed "particles of nanometer sizes are also called microplastics because there is no lower limit". Among the answers, a connection to water was also quite prevalent, with answers including wrong concepts like "the plastic particles are dissolved in water", more complex statements like "it is hard to filter them out of water because of their size" and a connection to the oceans in a few answers, mostly revolving around plastic waste in the oceans and a microplastic pollution of the oceans. There were also a few mentions of the prevalence of microplastics in the food chain. Some of the definitions also included a part on harmfulness to the environment, with statements ranging from "harmful for humans and animals" to "highly toxic to humans and animals". With these results, we report similar findings to literature (Janoušková et al., 2020; Raab & Bogner, 2021) and once again highlight the need of a more profound and detailed education on this highly relevant topic.

This point is further supported by a lack of knowledge on microplastic we found in the second part of the questionnaire. Here, we asked the students to rate on a five-level Likert scale whether they agree with statements on microplastics, environmental pollution by microplastics and sources of microplastics (see Table 3 for the statements and data). Here we can see that students tend to disagree with the statement that microplastics can be seen with the bare eye (M = 1.88, SD = 1.26), further supported by their tendency to agreeing that it can only be seen under the microscope (M = 3.72, SD = 1.35). This in stark contrast to the most common definition of microplastics, where small plastic particles with edges < 5 mm are defined as microplastics and therefore can easily be seen by the human eye, although not all microplastics are big enough to be seen. Further, students rather strongly agree that microplastics are harmful to humans (M = 4.60, SD = 0.73), animals (M = 4.68, SD = 0.63) and plants (M = 4.48, SD = 0.77). There is some evidence on the harmfulness of the particles, but from a scientific point of view there still is a lot of controversy and open to be tested.

Table 3. Questions asked on knowledge about microplastics in the pre-survey. The statements were rated on a five-level Likert scale.

Statement	M	SD	fully agree	tend to agree	neither nor	tend to disagree	fully disagree
Microplastic can be seen with the bare eye.	1.88	1.26	8 %	6 %	4 %	28 %	52 %
Microplastic can only be seen with a microscope.	3.72	1.35	30 %	46 %	4 %	6 %	14 %
Microplastic is harmful to humans.#	4.60	0.73	70 %	24 %	2 %	4 %	0 %
Microplastic is harmful to animals.#	4.68	0.63	74 %	22 %	2 %	2 %	0 %
Microplastic is harmful to plants.#	4.48	0.77	60 %	32 %	4 %	4 %	0 %
Clothes are a big source of microplastic.	3.84	0.89	24 %	44 %	24 %	8 %	0 %
Plastic bottles are a big source of microplastic.	4.40	0.67	48 %	46 %	4 %	2 %	0 %
Cars are a big source of microplastic.	2.94	1.12	8 %	26 %	26 %	32 %	8 %
Cosmetics are a big source of microplastic.	4.32	0.72	44 %	46 %	8 %	2 %	0 %
Plastic packaging is a big source of microplastic.	4.56	0.58	60 %	36 %	4 %	0 %	0 %

We report the mean and standard deviation for each statement as well as the distribution of answers rounded to the nearest integer percentage value (N = 49). Items that were originally phrased in a negative manner have been recoded for clarity. The recoded items are presented with a reversed phrasing to maintain consistency across all items and are marked accordingly (#).

However, perhaps most relevant to the students' daily lives and their sustainable behavior are sources of microplastics emission into the environment. Here, we report that students rather strongly agree that plastic packaging (M = 4.56, SD = 0.58), plastic bottles (M = 4.40, SD = 0.67) and cosmetics (M = 4.32, SD = 0.72) are a big source of microplastics emission and tend to agree that clothes (M = 3.84, SD = 0.89) are a big source of microplastics. Although both plastic packaging and plastic bottles are not the most relevant sources of microplastic emission, they are factors that are easily controlled by students in their daily lives, and they can actively reduce the amount of single-use plastics they consume. Furthermore, littering of plastic waste is a relevant factor, and well within the student's control. Awareness for this fact might positively contribute to a more sustainability-friendly behavior. For cosmetics, the amount of solid microplastic particles is in rapid decline and changing their consumption behavior might not affect their total microplastic emission in the way intended. Interestingly, they neither agree nor disagree ($M = 2.94$, $SD = 1.12$) on the statement about cars, although one of the biggest emission sources of microplastics remains individual mobility, mostly attributed to tire degradation. Although this is one of the biggest factors, it is often not in the students' control to lower the amount of individual transport taken by car. Altogether, it is not surprising that with the perceived harmfulness of microplastics, students consider changing their environmental attitudes (Kaiser et al., 2007). In the part of the survey that was given pre-treatment and post-treatment, we found that on a five-level Likert scale students significantly changed their perceived relevance of microplastics for their daily lives ($M_{pre} = 3.27$, $M_{post} = 3.90$, $t(48) = -3.92$, $p < .001$). Furthermore, we found a significant change in their prospective environmental attitude on the items "If offered a plastic bag, I take it" ($M_{pre} = 3.94$, $M_{post} = 4.23$, $t(47) = -3.47$, $p = .001$; recoded for clarity) and "I buy products in refillable packaging" ($M_{pre} = 3.37$, $M_{post} = 3.80$, $t(48) = -2.56$ $p = .014$), as reported previously (Majcen et al., 2023).

Conclusion

In conclusion, in this publication we showed that there is still a lack of knowledge on several aspects of the topic of microplastics like emission and harmfulness among students. As suggested in literature, there are not a lot of opportunities to learn about microplastics in a school context. Our cheap and accessible microplastic detection workshop not only aimed to fill knowledge gaps, but significantly impacted students' behavioral intentions towards sustainability. Our research underscores the vital role of practical, hands-on educational experiences in fostering environmental stewardship at an early age. By employing a simple yet effective protocol for microplastic detection, we provided students with tangible insights into the pervasiveness of microplastics and their potential harms. This approach not only demystified the science behind microplastic detection but also reinforced the relevance of individual actions in combating pollution. Such educational interventions, we believe, are crucial in cultivating an informed and responsible citizenry equipped to face environmental challenges. The significant changes in students' perceptions and attitudes post-workshop are indicative of the effectiveness of our methodology. It is imperative that we continue to refine and implement such educational strategies broadly, ensuring that future generations are better prepared to tackle the complex environmental issues that lie ahead.

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Food is Our Mission: An Interdisciplinary Approach to Teaching Food Science in Schools

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FoodEducators by EIT Food

Studies have demonstrated that interest in science is slowly decreasing as students advance in the school system. However, other studies have demonstrated that students have interest in nutrition and food, this interest can be leveraged to increase engagement with science education in general. In 2022, EIT FOOD under the scope of its FoodEducators brought together a team of international education and science education experts, to develop interdisciplinary teachers' resources, connecting topics of healthy and sustainable food, food science and food education. In the pilot phase the resources were tried and tested by teachers in 5 countries (Cyprus, Czech Republic, Israel, Hungary, Spain) with a reach of 97 teachers and 2123 students. The project was designed to demonstrate to the students both the global aspects of the food practices, such as sustainability of the food system and the local and personal aspects, or seasonal produce. Therefore, promoting the complex understanding of food as a socio-scientific issue. By using this framework, we introduce to students the inter- and multidisciplinary aspects of food science (and science in general) and strive to make both the subject matter and skills gained relevant to their lives.

Keywords: Food literacy, sustainable diets, curriculum development, European education

Introduction: The need for food literacy

Previous studies have demonstrated that interest in science is slowly decreasing as students advance in the school system (Fortus & Vedder-Weiss, 2014; Vedder-Weiss & Fortus, 2013). At the same time, different studies have found positive correlations between interest and various learning indicators, moreover, studies about interest in scientific issues found that students have interest in nutrition and food (Baram-Tsabari & Yarden, 2009; Swirski & Baram-Tsabari, 2015). FoodEducators aims at leveraging this student interest to encourage our youth to engage with some pressing food related challenges. These include issues such as obesity, food waste and environmental degradation. Supporting the next generation in learning more about the food system so that they can make improved food choices has never been more important. And despite the increasing challenges it is difficult to encourage the next generation to make improved food choices if their engagement and comprehension of food is poor if they are “disconnected from food in ways detrimental to their health” (Ryan, et al., 2018, p.2).

At EIT Food, promoting a holistic and expanded approach to food literacy has been at the core of both the Education and Public Engagement teams, and since its inception have been working on developing numerous educational programs, in k-12 as well as higher education, to promote it. Expanding on Vidgen & Gallegos’s’ (2014) conceptualizing of food literacy based on four basic abilities (plan and manage, select, prepare and eat), we added to each ability an additional sub criterion that includes the environmental and sustainability aspect, which is crucial to EIT Food mission. (see figure 1). Early in 2021, focusing on k-12 audiences, the first ideas that led to the creation of FoodEducators emerged. These were based on our analysis of the large number of EIT Food past projects that worked around Food awareness with young audiences (in Education and Public Engagement).

For instance, EIT Food supported:

- WeValueFood created a repository for food education material.
- Games of food developed an Escape game.
- Sea & Eat created eBooks for young kids.
- EIT Food School network created an educational app for preschools and an online game for primary school kids.
- Future Kitchen developed a Virtual Reality series.
- The Annual Food Agenda put together a variety of events.
- Food Science Class developed curricula for middle schools.

Those were very diverse and varied in their output and outcomes and were developed in isolation. In some cases, there was even a risk of duplication of the work. Moreover, most of those projects were ending in 2020-2021 and did not have any resources to further communicate and disseminate the content created.

Thus, at the end of 2021 the FoodEducators (previously Youth Mission) program was initiated. In this program we decided to focus on supporting k-12 educators and brings together a team of international education and science education experts, to gather all the lessons learned from the above listed projects and develop them into coherent interdisciplinary teachers’ resources. The (online) resources developed and designed by the expert group were curated as a set of lesson plans connected to topics of healthy and sustainable food, food science and food systems to be implemented in different grade levels and under different school subjects.

Figure 1. Food Literacy Components: For person and for the planet.

Adapted from: Vidgen & Gallegos, 2014.

FoodEducators: From conception to reality

In the pilot phase (Autumn 2022), the materials were tried and tested by teachers in 5 countries (Cyprus, Czech Republic, Israel, Hungary, Spain) with a reach of 97 teachers and 2123 students. In the next year, 2023, 150 teachers and 735 students from Poland and Turkey were also piloting the adapted materials.

As an international collaborative project, it was important for all partners to empathize that while “The human food system and international sustainability advice are both global in scope…. food practices are locally situated and personal” (Wilde, et al., 2021, p. 1). Thus, the materials and resources were designed to demonstrate to the students both the global aspects of food practices, such as sustainability of the food system and the local and personal aspects, such as seasonal produce. Therefore, promoting the complex understanding of food as a socio-scientific issue. By using this framework, we introduce to students the inter- and multidisciplinary aspects of food science (and science in general) and strive to make both the subject matter and skills gained relevant to their lives. In addition, it was also important to demonstrate how some issues are manifested on both levels – e.g the issue of food waste. Therefore, promoting the complex understanding of this socio-scientific issue.

Throughout the development and implementation of the project a strong emphasis was put on the question: “how is this relevant to my daily life?” and students are encouraged to critically consider and discuss this question. For example, when conducting a lab on yeast fermentation – a chemistry related activity – students discussed industrial uses of yeast and how their conclusions from the experiment are also related to cooking and baking at home.

Another important aspect of the handbooks is the emphasis on development of these important skills that are often absent from science classrooms:

- Critical thinking and open mindedness - the ability to critically reflect on our own practices, biases, and assumptions and understand how these influence our daily decision making.
- Media and social media literacy – the ability to evaluate the vast number of messages, posts, clips, news articles, and many more information sources without the need to learn large amounts of school science. This also includes the ability to search for reliable sources of information when needed.
- Science communication skills – the ability to communicate to a variety of audiences scientific knowledge and skills.

Working with and for teachers

In ESERA 2023 conference we presented a workshop that demonstrated two lessons from our resources (freely accessible online on our website: www.foodeducators.eu) and how they can be used in any classroom – easily adjusted adapted by teachers in different countries. The two lessons discussed in the workshop were:

1. Understanding food labels: Students are exposed to information on food labels from many online sources, and the ability to evaluate these sources is becoming crucial (Takahashi & Tandoc, 2016). The lesson also deals with common misconceptions in labels and how to handle the details and amount of information apparent on labels.
2. Food waste and food loss: In this highly interactive lesson students will learn about the damage caused by food loss and waste to the economy, environment and society and recognize ways to reduce food waste.

We also shared with participants lessons learned from interviews with teachers: every year we collect feedback from teachers who use our resources in their classes so that we can improve and further enhance the applicability of our content. In addition, in 2024 we launched a Teachers' Advisory Board with the goal of bringing teachers' voices and experiences from across Europe to our development and implementation work.

Contribution to science education practice

In our work with the FoodEducators project and resources we strive to engage with equity in science issues – this project was conceptualized as a framework for lessons and activities that can be implemented with great flexibility and for very diverse audiences. The team consists of partners from multiple countries bringing to the table multiple perspectives and languages. The resources and lesson plans were and are carefully translated to a variety of languages (Czech, Greek, Hebrew, Hungarian, Polish, Turkish, and Spanish) and every revision incorporates teacher feedback.

While emphasizing project-based learning strategies the project also promotes situating the "problem" (healthy and sustainable lifestyles) in the students' specific cultural context. Moreover, "In project-based learning, students engage in real, meaningful problems that are important to them and that are similar to what scientists, mathematicians, writers, and historians do" (Krajcik & Blumenfeld, 2006, p. 318). This approach has been found to be especially fruitful for promoting science literacy in the teen years (King & Henderson, 2018).

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Framing Ethical Issues About Climate Change on Climate Justice to Explore Pre-Service Teachers' Ethical Reasoning

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Climate crisis is an ethical issue besides being an environmental problem. Therefore, examining pre-service teachers' ethical reasoning about climate change is crucial since they will create future global citizens. Since climate change is an interdisciplinary field, not only science teachers but also English Language teachers are supposed to include reading activities on environmental topics in their classes and thus, contribute to their students' ethical values about these topics. Therefore, the purpose of this study is to investigate pre-service language teachers' ethical reasoning on climate change. We framed ethical reasoning on climate justice based on the theoretical background, which considers climate change as a social justice issue because disadvantaged communities are likely to be the most vulnerable to the impacts of climate change while they contribute least to causing climate change. The participants of the current study were 31 pre-service teachers (10 males, 21 females) who study in English Language Teaching Program in Faculty of Education at a private university in Turkey. The data was collected from the reflective forms that the participants filled and teaching designs that they created on climate justice (CJ). The results of the study revealed that while the participants generally emphasized CJ as the principles of social justice including human rights, access to resources, equity, participation in decisions on personal and social issues, they were challenged to design a teaching that would bring these values to the classroom. The findings of this study support the argument that a transformative pedagogy reframing climate change education on CJ is needed to prepare students for finding solutions of today's climate crisis. Designing teacher education programs considering the holistic and transformative pedagogy reframing climate change education on CJ may help for our sustainable future.

Keywords: Climate justice, ethical reasoning, pre-service teachers

Introduction

Global warming is the biggest challenges to social justice (World Bank 2012). The world's richest countries have contributed most to the problem; therefore, they have a greater obligation to take action (Adams & Luchsinger, 2009). It is an economic, social, ecologic, and political issue as well as an environmental problem that requires an ethical perspective (Akkuş, 2021). Climate change is an ethical issue; therefore, the consideration of its global impacts is an ethical responsibility (Bazzul, 2020).

Stapleton (2017) suggested framing climate change education around social justice and addressed this issue as climate justice (CJ). She argued that CJ is a social movement that uses social justice to frame climate change and suggested contextualizing climate change in CJ during teaching not only science, but also social studies and humanities to create interdisciplinary connections and perspectives on the issue. However, it is worrying that teachers' insufficiency about CJ than activists and advocacy workers (Boon, 2015; McGregor and Christie, 2021). Rousell and Cutter-Mackenzie-Knowles (2020) argued the necessity of developing new approaches of climate change education to enable next generation to deal with scientific, social, ethical, and political aspects of climate change in a transdisciplinary approach. However, scarcity of research studies investigating ethical reasoning of climate change and lack of consensus on how a holistic CJ education should be structured (eg Brister, 2014; Schreiner, Henriksen, and Hansen 2005) points out the necessity of exploring PSTs' ethical reasoning of CJ. Such exploration may bring new insight into teacher education programs regarding CJ. Environmental problem and environmental issues should not be the only responsibility of science lesson and science teachers. Since climate change is an interdisciplinary field, Teachers from all branches should contribute to the ethical values of their students for a life perspective in harmony with the nature (Frimpong and Obeng, 2022; Lehtonen, Salonen and Cantell, 2019).

Looking at the national curriculum reveals that environmental issues are included in English language lessons as well as science lessons. Foreign language teachers have no obligation to teach what caused acid rain or the scientific foundations of the nitrogen cycle. However, they will have a share in gaining a perspective to the students with the readings and debates they will have using ecological terms. English language curriculum program in Turkey between the grades of 6-12 (MEB, 2018a; MEB, 2018b) covers the topics about environmental problems and ethical norms and values related environment like "*saving planet- what should we do to save our world*?" in 6^{th} grade curricular teaching subject (see table 1).

Table 1. Topics about Environmental Issues Covered in English Language Curriculum

Grade	Topic
6th	Saving Planet – What should we do to save our world?
7th	Environment – What should we do for our environment?
8th	Natural Forces
11th	Values and Norms
12th	Human Rights Alternative energy

However, foreign language departments are received very limited number of science lessons during their high school years and do not take a science-related course during their university education. Considering pre-service English teachers' have little background knowledge in science and environmental issues it is crucial to examine their reasoning on CJ. From this perspective, the purpose of this study is to investigate the pre-service language teachers' ethical reasoning on climate justice.

Method

In order to understanding the participants' ethical reasoning of climate justice, this study was designed as a qualitative and explored pre-service teachers (PST)' ethical reasoning by reflection forms and teaching designs. Study was conducted with preservice teachers from education faculty at private university at Turkey located in Istanbul. Thirty pre-service foreign language teachers (10 males, 20 females) who study in English Language Teaching Program participated voluntary in the study. During the fifth term fall semester, participants took the ethics and morality in education course. During this course, participant pre-service teachers focused on various ethical issues and one of them is climate justice. While PST' prepare their teaching design integrated with CJ, the researchers did not any recommendation or specify any of aims or method.

Data collection

The data from this study were collected by reflection forms and their teaching plans. In the reflection, they identified and justified CJ by answering the following questions: 'Which actions or choices do you think contribute to climate change? Do you think there is a relationship between social justice and climate change? Which one(s) of your action would you agree or refuse to give up? 'in their teaching designs, they discussed how they could design an instruction to teach these ethical issues in their own class. The researchers of the current study created a rubric to analyse the participants' reflections their explanations as high, moderate, and low level of reasoning, then scored each level of reasoning as 3, 2, and 1. What is expected from the PST's is to evaluate and criticize possible causes from ethical perspective, rather than listing the causes of the climate change. In summary, in the rubric, If PST successfully identified CJ issues with critical and holistic perspective, and then receives 3 points.

The researchers also created categories of ethical issues that the PSTs' teaching designs independently. After the teaching designs were evaluated with the rubric prepared by the researchers, the values that the participants aimed to include in their teaching designs were coded and categorised in each level. Inductive code generation and collective comparison were employed in the current study.

Findings and Discussion

The researchers analyzed the participants' scores of reflection to investigate their identification justification and aims of teaching in CJ. The results of the descriptive analysis showed that while pre-service teachers' definitions of the causes of climate change were moderate level (2. 55), their justifications for why this situation was an ethical problem remained at a low level (1.76). The participants listed various actions that cause climate change without justifying why these actions are ethical issues. Similarly, the findings revealed that the average score of the PSTs' reasoning level in teaching category remained at the medium level (2.19). This result indicates that they were challenged to reflect the values related to CJ into their teaching plans. The findings also showed that the activities that the PSTs created did not seem to actively engage students in the activities. They often prepared teacher-centred activities such as lecturing or narration through posters. The following quotations are examples of the activities that they created:

> We can stop climate change by talking to people by warning them about it. We can make them realize its danger. In the lesson, we can present photos and posters and explain what climate change is and what they should do to deal with it. (P4)

> Climate scientist can come to class and can give instructions to students… (P8)

> We can explain what plastics are and carry out a recycling activity. These activities increase awareness and pro-environmental behaviour (P12).

Qualitative analyses also showed that although they emphasized climate crisis in their teaching plans, no activity designs focused on valuing or the impact of environmental organizations.

The analysis of the PST's teaching designs revealed that the emphasized values about CJ were as follows: equality (16), respect to wildlife (4), responsibility

(9), equity (4), human rights (5), empathy (2), and solidarity (3). The PSTs evaluated CJ considering the principles of social justice including human rights, access to resources, equity, and participation in decisions on personal and social issues. One can infer from this result that framing climate change issue on CJ enabled PSTs teach the principles of social justice. The results of the current study thus highlighted revisiting climate change education in teacher training by framing the courses about ethics and climate change on CJ. Such kind of framing seems to have provided pre-service teachers to reflect their reasoning in a more organized and coherent way in favor of CJ.

However, it is evident from the analysis of PSTs' teaching designs that the participants see CJ as an equality issue rather than an equity issue. The distinction between equity and equality seems to be emphasized in deeper sense in teacher education.

Table 2 Pre-service foreign language teachers' reflection about climate justice

Participants	Empathy	Respect to wildlife	Responsibility	Equality	Solidarity	Human Rights	**TOTAL**
P1				•			1
P2			•	•			2
P3			•	•			2
P4				•			1
P5				•	•		2
P6						•	1
P7				•			1
P8				•			1
P9			•				1
P10				•			1
P11					•		1
P12						•	1
P13			•				1
P14				•			1
P15			•				1
P16						•	1
P17		•					1
P18	•		•				2
P19				•			1
P20				•			1

P21	•		•				2
P22				•			1
P23		•	•			•	3
P24				•			1
P25			•				1
P26				•			1
P27				•			1
P28		•					1
P29		•			•	•	3
P30				•			1
TOTAL	2	4	9	16	3	5	39

Eaton and Day (2020) criticized the current environmental education for not serving to raise scientifically literate individuals who can establish the relationship between science-technology-society and cope with the climate crisis. Results of the current study indicated the necessity of guidance during pre-service language teachers to generate their own teaching for creating such citizens. It is crucial that designing teacher education programs considering the holistic and transformative pedagogy reframing climate change education on CJ may help for our sustainable future.

If we want to raise individuals who critical thinker and produce solutions in environmental education beyond the level of basic knowledge, we need to set out with holistic education approach. For this, it is important that we know the readiness levels of teachers in all branches. The findings of this study support the argument that a transformative pedagogy reframing climate change education on CJ is needed to prepare students for finding solutions to today's climate crisis (Stapleton, 2017). Fine and Love Nichols (2021) suggested that sociolinguistic department may bring new light to constructing educational programs regarding CJ.

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Post-Development Perspectives of Sustainability in Discourses of Environmental Educators and Teachers

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Post-development perspectives of sustainability are visions that emerge in contemporary life. The main objective of this research was to identify discursive hybridisms between notions of development and post-development in the discourses on sustainability of environmental educators and teachers, using discourse analysis as a theoretical framework. We analyzed 47 texts produced by environmental educators and teachers in four in-service formation courses over the years 2018, 2019, and 2021. We identified that sustainability hegemonic discourses are present in the text as well as non-hegemonic perspectives. Hegemonic discourses are characterized by a view of nature as a resource to be explored, with the idea of environmental care being subordinated to the quality of human life and a sense of human distance and non-inclusion in nature. Some hybridisms and contradictions in the educators' discourses, occur though recognize of a human being as part of nature while identifying the Amazonian territory as suffering from destruction by human being, assuming a vision of itself separately from nature. Through the analysis, we have perceived that most of the non-hegemonic sustainability discourses occur in the texts written during the pedagogical activity in the forest after the walking on the trail. Being in the forest, having contact with non-urbanized environments is an important path for the emergence of non-hegemonic sustainability senses.

Keywords: Good living, discursive hybridisms, environmental praxis

Context and Objectives

The current era presents challenges to educational field pointing towards limits to the sustainability of human and non-human life. Environmental issues and conflicts are conceived from the ecological, socioeconomic, political, and cultural stemming from differences in socio-ecological uses and degradation of nature by human beings. This leads to a vision of environmental literacy oriented towards political participation of citizens to face series of environmental challenges and gets justice (Espinet et al, 2023).

In addition, international theoretical debates in the heterogeneous field of environmental education configure a sort of terms as education for sustainability, education for sustainable development among others, with differences of meaning between the global North and South. This means that there are disputes about the meanings of the term sustainability that are fought discursively. While certain sustainability discourses rely on technological development (end-of-pipe technologies) to overcome unsustainability of the world, others question the very system of organizing social life that generates them. However, development and post-development discourses are present in discourses on sustainability of environmental educators and teachers.

This research presents discursive hybridisms between notions of development and post-development in the discourses on sustainability of environmental educators and teachers configuring a challenge of the "viable unknown" (Freire, 2016). It aims at exploring: (a) What are the meanings of sustainability that emerge in the training of environmental educators, and how do social attributes influence their practices or discourses? and (b) How can environmental educators be prepared to address non-hegemonic sustainability and post-development issues to overcome Anthropocene while considering the unique socioenvironmental challenges in the Global North and South? The objective of this research was to identify discursive hybridisms between notions of development and post development in the discourses on sustainability of environmental educators and teachers using discourse analysis.

We characterized conditions and contexts of its emergence based on experiences and meanings of sustainability of teachers and environmental educators from Pará, Brazil, which announce new possibilities to formative processes for non-hegemonic views of sustainability. The education training processes were mainly held in an outdoor space a protected area of the Amazon Biome for sustainable use (FLONA de Carajás) where vegetal and mineral exploration; visitation activities; environmental management and environmental education projects are developed (ICMBio, 2016). This research generated a substantial debate about common challenges of theoretical references and methodological proposals that we have experienced in Brazil and that could be re-geolocated in European contexts and collectively.

Theoretical Framework

Post-development perspectives of sustainability (Kothari et al., 2014; Freire et al., 2022) are visions that emerge in the Global North (such as degrowth and ecofeminism) and in the Global South (Swaraj, Ubuntu, Teko-porã, Buen Vivir). Instead of considering homogeneous proposals, we value this approach in the plural sense. Together they face some weak views of sustainability and a sense of development. Those perspectives do not assume the capitalist logic of economic growth as a pillar of a sustainable future (Scarano et al., 2021). Therefore, we have been engaging in dialogues with these perspectives that advocate new realities and new futures. With a non-hegemonic or post-developmentalist view of sustainability, they already got to work the wrong way of capitalism. They are together as a capitalism mazing out.

The “Buen vivir” (Good Living) approaches have different ontological matrix and, refers to a way of life in harmony with nature and other human beings. It encompasses cultural paradigms inspired by the ancestral culture of the indigenous Andean-Amazonian cosmovision, as well as philosophical currents of thought such as socialism, “pachamamista” and post-developmentalism (Cubillo-Guevara & Hidalgo-Capitán, 2015). According to post-development perspectives, besides from the recognition of injustices, violence, and socio-environmental problems, educational processes should center on the inequalities present in a society of consumerism. Also, the idea of nature having rights is emphasized and the capability of individuals to bring about social change in addressing environmental injustices is acknowledged.

We delve into the frameworks of post-critical theories and their contributions to overcoming the characteristics of modernity, such as universalization, hierarchization, knowledge fragmentation, and a lack of understanding of complexity (Carvalho, 2012). This includes the valuation of reason over emotion (Giddens, 2002), the failure to perceive nature in human beings (Menéndez, 2018), and the isolation of humans from nature.

According to Kawahara and Sato (2017), pathways for environmental education within the framework of post-critical theories consider the individual and intersubjective relationships of human beings, creating new possibilities for practices that strengthen human connections. Furthermore, by valuing affectivity and subjectivity, new avenues for environmental education are initiated (Iared & Oliveira, 2017; Iared, 2019; Kawahara & Sato, 2017; Payne, 2016; Rodrigues, 2019). These avenues enable a reevaluation of the meanings of relationships with nature and bring about advancements not only in theoretical aspects but also at the level of experiences and educational practices.

Considering the challenges of the 21st century, the sense of urgency for the transformations sought in Environmental Education takes on a leading role, accompanied by a reconsideration of some of the field’s postulates. Certain positions previously considered naive gain strength from a decolonial discussion, promoting the rise of subjectivities, and shaping a relational-affective turn in the field of environmental education.

The relational-affective turn involves challenging the anthropocentric view of the world, moving towards a perspective where the social is seen as an “ensemble” of human and non-human actors, each with their respective agencies and movements (Latour, 2005). This notion of agency recognizes the affected and affecting condition of all actors that constitute the world we inhabit. An essential requirement involves reconfiguring language, concepts, and ethical care practices to envision a "more than human" world (Panelli, 2010). Beyond introducing novel research methodologies, the relational-affective turn advocates for a perspective that emphasizes multiplicity and a network of actors. These multiplicities of actors are viewed as dynamic entities that amplify, create tension, and reshape the understanding of socio-environmental processes and phenomena (Lara, 2015).

Analysis of any discourse in contemporary societies must consider how different discursive types are mixed. It is a hybridity characteristic of complex modern discourse. Hybridity analysis has structural and interactional dimensions. The structural attends to how interactions are constrained by the networks of orders of discourse, while the interaction dimension attends to how that network is interactionally workers and potentially restructured though a rearticulation of resources. To access post-developmentalist approaches of sustainability we present some implications in educational processes that can: (i) promote biocentric or cosmo-centric approaches in educational processes considering the rights of nature; (ii) value the dialogue of knowledges giving voice to new social actors including social demands, historically ignored, and forgotten; (iii) generate transformative experiences of the self and society in eco-pedagogical proposals of reconnection, and foster responsive ethics in relation to other ontologies (Rufino, Renaud Camargo & Sánchez, 2020).

Methodology

This study has been carried out in a protected area in Amazonian rainforest, in the North of Brazil. It is an area that has been explored by miners since the sixties of the last century. Nowadays it is under preservation, but mining activities are not forbidden there in that case. The preservation area is part of a mosaic of several others preservation areas including areas for preservation of sociobiodiversity represented by indigenous people who live there.

The empirical context of the research is a formative process of the environmental education project of the Program of Limnological Studies in National Forest of Carajás. The activities value the territory, the aesthetic dimension (affectivity), social participation, cultural diversity, discussion of local conflicts and the trail as an outdoor space for the formation of the subject. The teaching training process is part of a scientific program of research in the area. We support environmental educators and teachers at local schools promoting outdoor activities as a didactic moment (4 hours) in the training process. Afterwards, they could make it with their students. For this study we analyzed narratives that were generated during different teaching training process.

During outdoor activities the walk is almost 3 thousand meters inside Amazonian rainforest. Didactic activities were planned before walk, but during the walk it has emerged some specific topic to talk related with the specific moment on trial, some animal, or tree, about something that happened, and something that is on the way that have caught our attention. Some aspects of the walking were registered by participants, and we could saw in the narratives. And we used it for analysis.

We analyzed 47 texts produced in four in-service formation courses over the years of 2018, 2019 and 2021. Three of these moments were pedagogical activities on the 'Lagoa da Mata' trail that generated different narratives about the experience of participants during walking on the route. Another activity was held prior to the outdoor moment and involved a proposal for constructing text on environmental issues in the local territory. To identify sustainability perspectives in the discourses of environmental educators and science teachers, we performed discourse analysis (Gee, 2011) on these narrative texts. After reading the texts, we identified the following idea units: (i) subject positioning (in relation to nature); (ii) social actors in the territory; (iii) self-reflection and reconnection experiences; (iv) collective positioning and responsive ethics.

Results and Conclusions

First of all, results show that when environmental educators and teachers have written about issues of mining, their discourses of sustainability assume a pragmatic perspective of the "necessary wicked problem" characterized by the development approach, while not engaging into deep reflection on what socioeconomic models are behind the environmental transformations nor the contradictions of the development model that deepen some injustices nor process of objectifying nature and generating inequalities and oppressions among some groups were present in the discourses analyzed.

The order of capitalism seems be mandatory in the discourses, serving in the real world as "a justification both for capitalism and for the criticisms that denounce the gap between the actual forms of accumulation and the normative conceptions of social order" (Chiapello & Fairclough, 2002,187p.). We found these narratives in all sets of texts, but only one participant identified the local mining as responsible for the mining activity. We could observe the dominance of the development approaches in the discourses of the participants. it means that ways of understanding nature from commercial bases are dominant ways of making meaning in a particular order of discourse.

In addition, the population was mentioned in a generalized and passive way, who do not recognize the value of the biome nor identify with it and who need to be made aware and educated. Another absence in the discourses involves the local indigenous issue, mentioned only in a text related to their occupation in the territory in the past, although there is a presence of Xikrin ethnic populations close to the FLONA.

Otherwise, in the sets of texts produced on a pedagogical activity after walking on the trail, we could perceive some discourses that approach non-hegemonic perspectives of sustainability in two ways: (i) positions of belonging to nature and valuing harmonious relationships between human beings and nature, e.g. "we see that we are part of nature" and (ii) recognition of non-human elements as subjects and as actors (as a producer of actions), e.g. "the forest was happy"; "I could feel the hug of nature", "animals welcoming us and the wind massaging the skin", "the forest [...] just asks us to respect it". The experience of being in the forest promoted a feeling of connection and belonging to nature, reflection about personal and professional practices, sense of perception as a way of perceiving nature toward social changes. In addition, we identified discourses of collective positioning and responsive ethics about nature conservation, human actions of environmental destruction, importance of social mobilization for conservation besides individual actions. Non-hegemonic sustainability discourses can lead to environmental literacy committed to social transformation.

A desirable environmental literacy could contribute to (i) redesign of public policies to value the rights of nature; (ii) recognize the presence of indigenous groups in the active role of the preservation of the area and (iii) co-manage some uses of the nature mainly mining activities as in the case of the National Forest of Carajás. Research and training for teachers should focus on critically examining current systems, with a particular emphasis on the role of science, education, and environmental science in addressing the unique challenges and inequalities of specific areas. This approach will enable a practical approach that is dedicated to addressing local struggles. Discourses, understudy as part of an action, reveal some aspects of the notion of environmental praxis of the environmental educators and teachers allowing to reflect on ways to connect theory and practice, expanding the concrete possibilities of social transformations. Discourses encompass visions - depictions of potential, possible, or desirable scenarios for the future of the Amazonian rainforest, for instance. The concepts related to the knowledge economy and knowledge society fall into this category, representing visions of conceivable future states, often referred to as "possible worlds". These visions have the potential to be translated into tangible practices, wherein envisioned activities, subjects, social relations, and more can materialize into actual occurrences promoting the "viable unknown" as we already pointed. Considering the challenges towards sustainability, these visions play a crucial role in shaping practices addressing these challenges.

The non-hegemonic discourses of sustainability recognize the voice of nature and are committed to the diversity of knowledge, practices, and ontologies. These links allow us to advance in the conception of sciences and their teaching that the sciences are not must impose structures in the study of the world, and that the protagonists must be the questions, problems and conflicts experienced by the participating people and collectives. In this sense, making decisions to act in society involves starting from connections between scientific knowledge and "real felt" ethical and political questions that enable emerging non-hegemonic discourses.

Among the list of political trends in environmental education, the following stand out: democratic participation, political reflection, deliberation, and political moment. Each proposal has similarities and differences to the objective of how to organize life in society. Develop reflexive investigations into current systems based on the challenges of the territory and especially on the role of science education and environmental education advances in gaps and contributes to its sociopolitical turn of science education.

The study shows that post-development perspectives of sustainability highlight that there is no universal or Eurocentric model of development to be followed: there is not only one grand meta-narrative about development and sustainability. To summarize, to achieve a desirable future, we as a global citizen need to explore creative and diverse alternatives in the present.

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Implementation of Act 27,642 about healthy diet promotion in a secondary school of Argentina based on the ROSES project

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The central aim of this research is to know the attitudes and interests of a chemistry course students in a secondary school in Argentina as regards nutrition in order to develop an adequate didactic sequence. To get to know the interests about nutrition, the relevant items of the ROSES (the Relevance of Science Education - Second) questionnaire were used. Based on its results, most of the students are interested in food production and preservation, and in healthy diets. Besides, a didactic sequence focused on the front-of-package nutrition labeling and its subsequent reading was developed. The didactic sequence was positively valued by students in relation to its usefulness, their interest, and a critical citizenship formation. The didactic sequence and students' interests coincide with the content proposed by Act 27,642 about healthy diet promotion by introducing food education in schools to exercise the right to health and nutrition.

Keywords: Food education, students' interests, healthy diet promotion Act.

Introduction

Attitudes conceptualization in relation to science in scientific education presents multiple viewpoints that include views from students and professors (Kolbe & Jorgenson, 2018). As a way of sytematizing the various objects of attitudes and integrating technology as part of society, Vázquez & Manassero (2017) proposed a taxonomy to classify the potential objects of "those attitudes related to science" in three dimensions.

More than twenty years ago, the Relevance Of Science Education (ROSE-2002) project was developed, whose goal was to diagnose various affective and attitudinal aspects related to Science and Technology learning. In western countries, students showed a generalized pattern of discontent towards science and technology. Nutrition was part of these discontent items. The lack of relevance of school science to students is probably the main barrier to good learning and the development of interest towards Science and Technology (Manassero-Mas & Vázquez-Alonso, 2021).

In order to update and compare the evolution of students' attitudes about Science and Technology, a new edition of the ROSE (named "the Relevance Of Science Education - Second") project has been started. ROSES-2020 allows getting students' viewpoints about various affective factors that make up their attitudes, preferences, experiences, and motivations in science learning (Jidesjö, Oskarsson & Westman, 2021). In a first study conducted in Spain, it was revealed that most of the topics in which students are interested are not commonly found in science curricula in secondary school (Manassero-Mas & Vázquez-Alonso, 2021). While those topics which minimally arouse students' interests are found in school curricula (Manassero-Mas & Vázquez-Alonso, 2021). Among these topics, there is nutrition, which lack a clear approach in secondary school (España et al., 2014).

ROSES-2020 project contributes to increase society safety in different aspects related to literacy in Science and Technology. A particular aspect of this knowledge is the contribution to food security through those items that name illnesses, food handling and preservation, and proposals to a healthy nutrition, as well as the specific contribution to science to improve these social aspects.

In 2021 in Argentina, Act 27,642 about Healthy Nutrition Promotion was issued (https://www.argentina.gob.ar/), whose main goal is to guarantee the right to health and nutrition in the population, and to warn consumers about the excess of components such as sugar, sodium, saturated fats, total fats and calories, based on clear and timely information of packages. Nutritional and food education is included within that Act in the country together with the front-of-package nutrition labeling and other aspects related to containers. It is important to highlight that in Argentina, and mainly in the province of Buenos Aires, the teaching of nutrition topics present a biological approach with no deep connection with health topics (Rivarosa & de Longhi, 2012; Lampert & Porro, 2022). On the other hand, there is talk of a healthy, safe and sovereign diet from the conception of social policy with a rights-based approach since our country has not only adhered to different International Covenants and Treaties on Human Rights, but also the Reform Constitutional Law of 1994 included them within the National Constitution in Art. 75. Inc. 22 (Antún et al., s/f).

Beyond the Argentine legal discourse, it is important to point out that food is transversal to several of the Sustainable Development Goals of the United Nations 2030 Agenda and that it allows its educational perspective to be encompassed within SDG 6 of Quality Education. Since, to talk about quality education, training in current issues and food, and especially food safety, is one of them.

On the other hand, many aspects of daily life, such as food practices and the contracts that are made daily to carry them out, are regulated by a system of rules that seek to protect the population in essential habits. Beyond the degree of knowledge that citizens have of these rules, the law provides fundamental tools and starting points for an adequate exercise of rights in the commercial operations that are necessary to acquire food. Ultimately, food education based on a rights-based approach will allow students to acquire tools that allow them to function in daily life (Lampert & Crivaro, 2023). Food education is part of scientific education in order to raise awareness about food issues (Lampert & Porro, 2022 a) and that would allow people to modify their eating behaviors (Martínez et al, 2018). This profile adopted by food education is positioned as a tool that allows the development of different competencies and critical thinking skills that lead students to decide what to eat and how, to maintain healthy conditions, and at the same time, correctly handle food in a safe manner. to prevent different food poisonings (Casas-Quiroga & Crujeiras-Pérez, 2019).

A preliminar study of the ROSES project in Argentina has obtained similar results to those in Spain about the nutrition topic. Those aspects which students seem keener on in relation to nutrition are not included in the school curriculum (Lampert & Porro, 2022 b).

Methodology

The purpose of this work is to analyze the attitudes of students from fifth grade of a secondary school in Quilmes (Buenos Aires, Argentina) about nutrition, and to develop an appropriate didactic sequence. ROSES' target population are students older than 15 years who are in the final stage of mandatory education. The sample of this study involves 25 students of a chemistry course (11 boys and 14 girls) who validly answered those items of the ROSES questionnaire related to nutrition. Students express their interest about each nutrition topic in the answer scale Likert of four points, established as 1 (indifference or disagreement), 2, 3 and 4 (interest or agreement), on which a weighted average of responses is estimated. Results are expressed in percentages following the categories of agreement or interest (topics or items defined as 2, 3 and 4) and indifference or disagreement (topics or items defined as 1). From those results, a didactic sequence is developed according to interests, and it is valued by students by means of a survey.

The items related to nutrition in the ROSES questionnaire are the following:

1. What the dependence is like among people, animals, plants and the environment.
2. What to eat in order to stay healthy and fit.

3. What can be done to guarantee clean air and drinking water.
4. How to control epidemics and diseases.
5. How to improve harvests in yards and farms.
6. Organic and ecological agriculture without using pesticides, agrochemicals and artificial fertilizers.
7. How different types of food are produced, kept and stored.
8. Benefits and possible dangers of genetically modified organisms in agriculture.

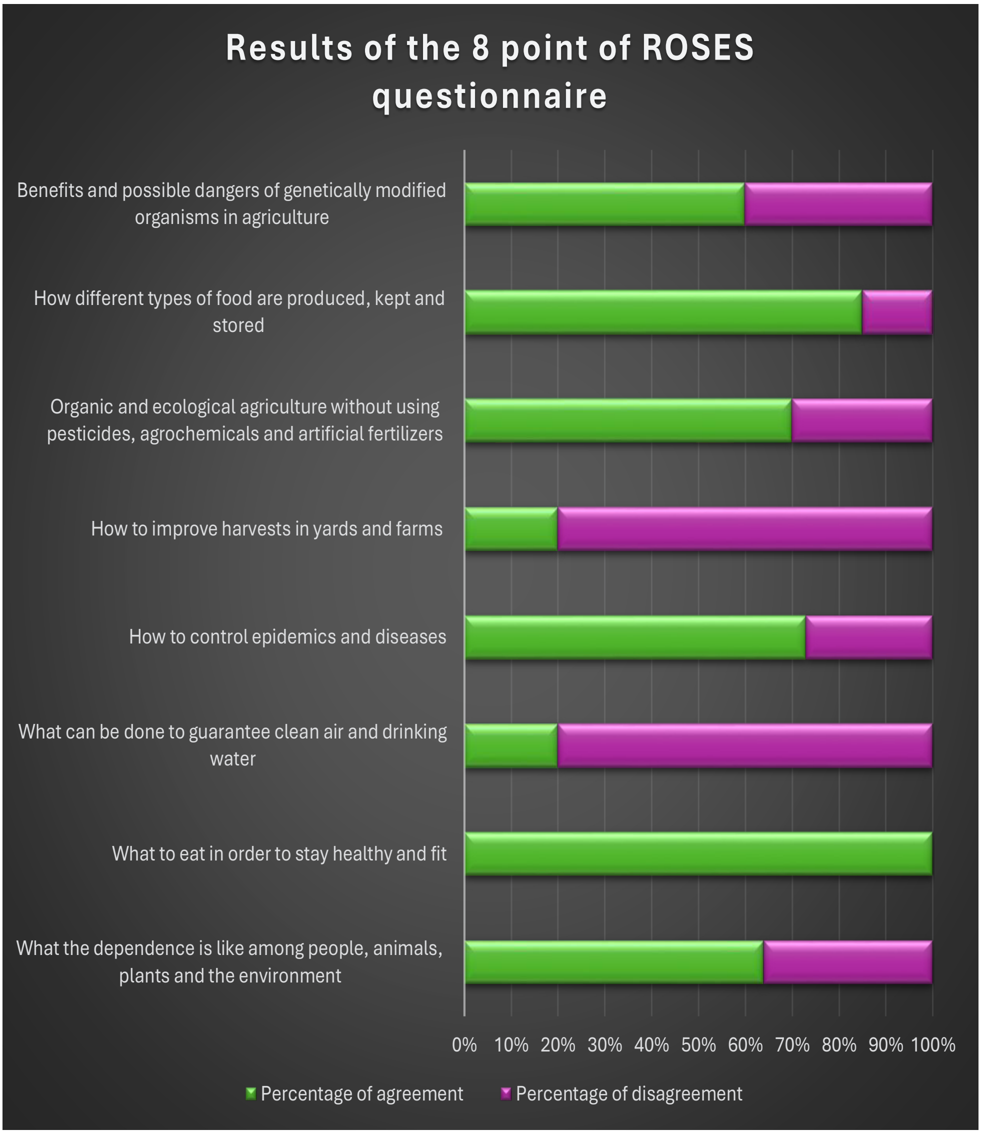
Results

The results of the 8-point ROSES questionnaire related to nutrition are presented below and in graph 1:

1. What the dependence is like among people, animals, plants and the environment (36% of disagreement and 64% of agreement).
2. What to eat in order to stay healthy and fit (0% of disagreement and 100% of agreement).
3. What can be done to guarantee clean air and drinking water (80% of disagreement and 20% of agreement).
4. How to control epidemics and diseases (27% of disagreement and 73% of agreement).
5. How to improve harvests in yards and farms (80% of disagreement and 20% of agreement).
6. Organic and ecological agriculture without using pesticides, agrochemicals and artificial fertilizers (30% of disagreement and 70% of agreement).
7. How different types of food are produced, kept and stored (15% of disagreement and 85% of agreement).
8. Benefits and possible dangers of genetically modified organisms in agriculture (40% of disagreement and 60% of agreement).

The results obtained from the questionnaire are presented in figure 1:

Figure 1. Results obtained



The items that received a high percentage of agreement were those associated with what to eat so as to stay healthy, organic and ecological agriculture, and how different types of food are produced, kept and stored. Following those results, a didactic sequence was developed that consisted of working nutrition aspects from a Science, Technology and Society (STS) approach. Therefore, the following aspects were included: history of the Argentinian nutrition legislation, nutrition labeling (according to Act 27,624), food production, and the risks associated to biological and chemical pollution of food. The didactic sequence had an exhibition section in charge of a Food Engineering professional (chemistry professor) and an invited lawyer, and a practical section of different nutrition labeling analysis.

The didactic sequence that was carried out is presented below:

Title: Chemistry and food.

Goals:

Carry out an educational interpretation of Act 27,642 and understand the subjects obliged to comply with the regulations.

Understand the composition of the different food groups in order to establish the critical nutrients that must be detailed on the product packaging.

[1]. Based on the comparison of the labels of the two drinks, what precautionary legends and/or warning seals should be incorporated into the labels?

[2]. Based on the label of drink A, indicate its mandatory and optional information.

[3]. How is drink A different from drink B?

The following table presents an image of the labels of foods A and B mentioned in the previous instruction (table 1):

Table 1. Label of the drinks used for the educational proposal.

Drink A

Drink B

[4]. Based on the provisions of Act 27,642, indicate whether or not the following cases are subject to obligated entities, according to said rule:

- A friend makes caramelized sugar, puts it in a paper wrapper and gives it to me so I can share it with my family.
- A bakery bakes sweet bread, puts it in a branded container, and sells it at its store for Christmas.
- A farm makes different types of sausages, packages them and sells them to different stores in the city.

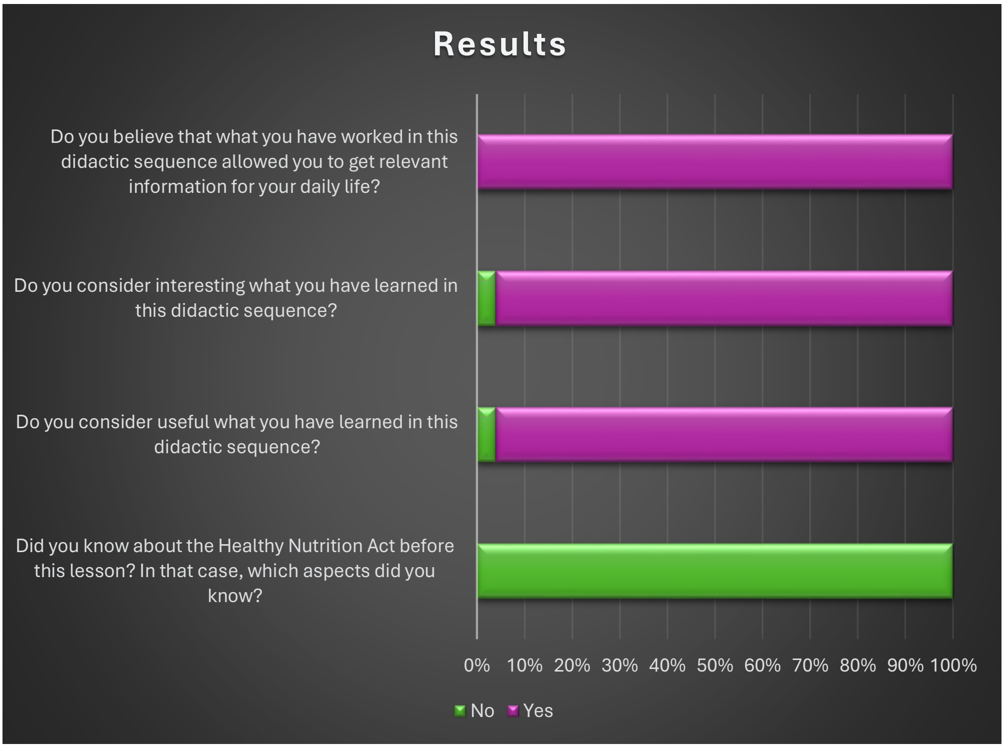
- A bakery that creates its own line of dairy products and offers them for sale on its shelves.

Once the didactic sequence was developed, an interview was conducted to assess the proposal. The following questions were part of the interview:

1. Did you know about the Healthy Nutrition Act before this lesson? In that case, which aspects did you know? Where did you hear or read about it?
2. Do you consider useful what you have learned in this didactic sequence?
3. Do you consider interesting what you have learned in this didactic sequence?
4. Do you believe that what you have worked in this didactic sequence allowed you to get relevant information for your daily life?

The results obtained from the evaluation of the proposal are presented in figure 2.

Figure 2. Results obtained



From survey results, more than 90% of students indicated the didactic sequence to be useful and interesting. In addition, they pointed out that it allowed them to understand and comprehend the nature of food production, and to develop skills for reading containers. An interesting analysis is the result of question 1. Very few students knew the Act; most of them thought it was about the octagons in food containers and not about other legal, economic, social, cultural and educational aspects.

Conclusions

Working from students' interests and attitudes allows a better understanding of Science and Technology. In this particular case, nutrition interest made possible the incorporation of food education aspects as established by the Act. It also made the proposal be positively valued in relation to interest and usefulness. On the other hand, these researches allow assessing food education as part of health education since in many countries, such as Spain and Argentina, nutrition is not treated from a full and comprehensive approach, but rather from a biological or medical one.

This work marks the beginning of different educational proposals that will allow us to continue working on the Healthy Eating Promotion Law. Likewise, the importance of working on the legal framework based on the interests of the students and the context of the educational institution is highlighted.

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Scientific Holism ('Two-Eyed Seeing'); bringing Science|Environment|Health issues into science teaching

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Health, environmental and especially medical issues are still underestimated as social science topics in science education. They play an important role in the lives of future citizens and at the same time increase the motivation for science learning for many pupils, especially girls. This article describes a didactic approach that is suitable for integrating these topics appropriately into science lessons. It is proposed to call it scientific holism and the heuristic it contains synoptic knowledge transfer (based on the philosophy of Willfried Sellars) or two-eyed seeing (based on an indigenous approach from Canada). The article presents a qualitative study with student teachers of natural sciences in which this approach was tested and further developed in the sense of participatory practical research. The resulting model is based on a double (or multiple) transfer between the scientific and students' lifeworld image. The teacher switches back and forth between an explanatory expert role and a hermeneutic interpreter role, and thus is alternately committed to the scientific image and the lifeworld image of the pupils. A characterisation of the two images was developed on different levels, which was helpful for the student teachers when planning, implementing and discussing their miniatures.

Keywords: Health Education, Scientific Literacy, Holism

Theoretical Background

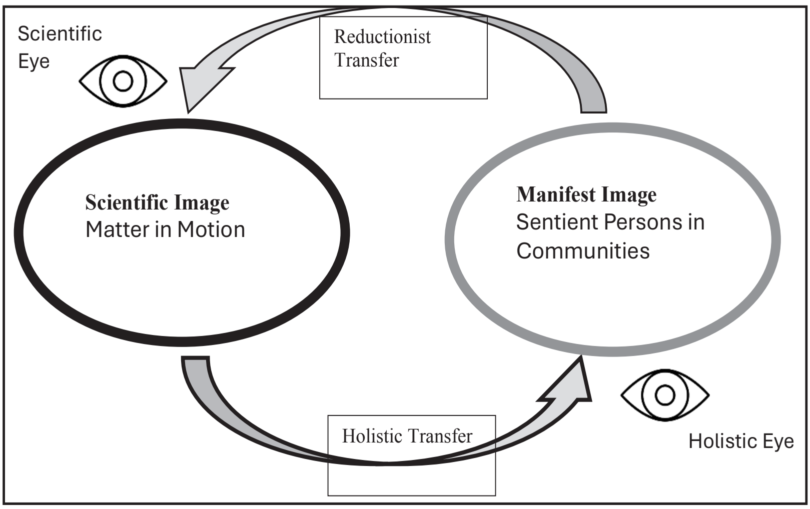
The Science|Environment|Health Pedagogy

Science|Environment|Health is a new science pedagogy that pursues the vision of promoting the mutual benefits between the three educational areas of science education, environmental education and health education (Zeyer & Kyburz-Graber, 2012). Health and especially medical contexts in science education have been underestimated to date. They are socio-scientific issues par excellence, with a clear scientific content and an equally strong emotional and social connection. They are important for the education of informed citizens and also improve the motivation of pupils for science lessons (Keselman et al., 2018).

Unlike classical science contexts (the epitome for example: the physics of planetary motion), they call for a new concept of scientific literacy different from the classical one, such as the theoretical framework used in the 2006 PISA project, which is very common in science didactics (Bybee, 2012). The core of such concepts is defined by scientific competences. According to this, a scientifically educated person must be able to recognise scientific issues, explain phenomena scientifically and rely on scientific evidence. However, this approach is often not enough when it comes to health and, in particular, medical issues. Although these elements are of central importance, an additional interpretative element is missing, which can only be provided by people, for example patients (Gerber & Kraft, 2014). This became very clear during the COVID-19 pandemic. Facts are often provisional in medical contexts and their final meaning is disputed. This must be negotiated socially. If too little consideration is given to this, individual and social mistakes are made that can cause considerable problems.

In the last ten years, voices have therefore become louder calling for a holistic approach to Science|Environment|Health. But what exactly could holism be in the sense of this approach? And in particular: how can a holistic approach be integrated into Science|Environment|Health without losing touch with sound scientific considerations? We have suggested that Sellars' concept of the Synoptic View (Sellars, 1962), as recently elaborated by Esfeld (2020), could provide a philosophical background for these difficulties (Zeyer et al., 2023). We also pointed out that a similar concept has been used for decades in Canadian science education with Indigenous students, where it is called Two-Eyed Seeing (Bartlett et al., 2012). Figure 1 shows a model of our approach to Scientific Holism, based on Sellars' philosophy and the indigenous wisdom of Two-Eyed Seeing (Zeyer et al., 2023)

Figure 1. The ontological model of scientific holism and synoptic knowledge transfer ('Two-Eyed Seeing') (after Zeyer, 2022)



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Scientific holism is based on two fundamental ideas from Sellars' philosophy and one from Indigenous Two-Eyed Seeing:

Sellars first basic idea is that the world as it is does not reveal itself to us directly, but that we see it with two eyes, so to speak, a scientific eye and a holistic eye (Two-Eyed Seeing). This results in two images of 'the world' that are complementary, i.e. mutually exclusive and supplementary, the scientific and the manifest image. The trick is to keep an eye on both images without neglecting one of them. In this metaphor, complementarity means that you can only ever open one of the two eyes. The other is then necessarily closed. In principle, you have to constantly switch back and forth between the two eyes ('eye switch').

Sellars' second basic idea is that complementarity is not located on the epistemological level (i.e. what can be known), but on the ontological level (i.e. what is). The scientific picture is made up of things that are primarily characterised by their relative positions to each other (i.e. relative distances, indicated by numbers). In the example of planetary movements, it is logically the sun and the planets. In the example of COVID, it is viruses, receptors, cytokines, etc. The aim and strength of the scientific picture is to explain these relative positions and predict their change. This is self-evident in the planetary example, but when analysed closely it also applies to the scientific picture of the pandemic, and ultimately to every (natural) scientific fact. The scientific picture is therefore atomistic, quantitative, explanatory and predictive. The manifest image is made up of people. They are characterised by social relationships in a community. To characterise these relations, we use sense experiences, qualities (beautiful, dangerous, important, etc.) and norms (rights and duties). The strength of the manifest image is to open up meaning and significance. In particular, the concept of freedom only makes sense in the manifest image and in the context of communities. The manifest image is therefore holistic, qualitative, interpretive and adaptive.

The third principle is called the 'TES approach with epistemic insight' (Michie et al., 2023), and refers to the inclusion of the context of knowledge and the ways of understanding that knowledge. It points out that sharing knowledge and understanding each other is a collaborative process on equal terms that requires what has been called the C4-R4 philosophy. C4 stands for Co-learning, Co-designing, Co-creating and Co-sharing, while R4 means good Relationships based on Respect, Responsibility and Reciprocity, as the bedrocks of an eye-level process (Hogue and Provost, 2023). C4-R4 has been developed to guide TES between Western science and Indigenous Wisdom. This article argues that it can be extended to Scientific Holism and the continuous and systematic transfer between the scientific image and any (including Western) manifest images.

In principle, the changes in Figure 1 can occur in different orders and without restriction. It should be noted that there can be a variety of manifest images (depending on the people and communities involved), while the scientific image is always included. It is considered - with due caution - as a singular image, for example in the sense of the family resemblance approach (Erduran & Dagher, 2014).

The scientific holism approach directly reflects the basic structure of socio-scientific issues, as it combines a reductionist, scientific image with holistic, social images on a level playing field. This becomes particularly clear in the indigenous approach of Two-Eyed Seeing, which is also translated as the gift of multiple perspectives. Following Sellar's terminology, one could also use the term synoptic knowledge transfer. The complementary juxtaposition of the scientific and manifest world views in Sellars' work is probably not only coincidentally similar in structure to the concept of complementarity in quantum physics. While the indigenous approach of Two-Eyed Seeing emphasises more the essence of the manifest worldview as 'full' truth, Sellars' Synoptic View conversely insists on the indispensability of the scientific worldview as equally 'full' truth.

Research Question

The aim of this research project was to test the model of scientific holism in a course with student teachers of sciences education and to develop it into a didactic model for science lessons. In particular, the aim was to investigate whether the approach would lead to the integration of health and medical issues in science lessons.

Method

The study examined an introductory course for student teachers of science education at the Lucerne University of Teacher Education. The 63 students, 29 women and 34 men, were between 21 and 45 years old and had different educational and professional backgrounds.

The students work in groups of 2-3 to create short teaching sequences, so-called miniatures (Zeyer & Welzel, 2006) prepared. They carried out these miniatures with their colleagues as their 'students'. These short teaching sequences were analysed and discussed in the course. As part of the research project, Two-Eyed Seeing was used for the preparation, performance and discussion of the miniatures. Methodologically, the research process can be categorised as teacher-centred action research (Laudonia et al., 2017). The materials were analysed using qualitative content analysis, with top-down categories derived from the original model and bottom-up categories developed through axial coding (z.B., Berg, 2009).

Results

Overview of the Miniatures Created

In this paper, only the most didactically relevant results will be presented. Some of these have already been provisionally indicated in (Zeyer, 2022). A comprehensive paper is planned.

67 students took part in the module. 29 were female and 38 were male. Their average age was 24 years. Most of these students (54) had completed their secondary school education with a final examination, the Matura, and had then entered teacher training at the university of teacher education directly. Their teaching experience was limited to a first teaching placement at an external school. Seven of the students had completed another degree programme before entering teacher training, four had previously worked in another non-academic profession and two had previously been primary school teachers.

The 67 students were divided into three parallel courses, two with 24 students and one with 19 students. The courses each lasted 12 weeks and were structured in the same way. The students organised themselves into groups of two or three. Each group chose one of the topics on offer and presented a miniature. This resulted in a total of 23 miniatures (Table1). Fifteen out of 23 groups used the topics of health, medicine and environmental health to shape their lifeworld approach. This is consistent with the assumption that topics related to health, medicine and the environment are attractive and can help motivate students to learn science (Zeyer & Dillon, 2014).

Table 1. The Themes of the Miniatures

Title	Topic	Description of the theme
1) Air pressure and altitude training	Blood and pressure	How the decrease in air pressure at altitude is used for endurance training
2) Blood pressure and thrombosis	Blood and pressure	Why and how thrombosis occurs in the low-pressure system of the blood circulation
3) ECG and atrial fibrillation	Blood and pressure	How wearables are used to detect atrial fibrillation
4) Measure blood pressure correctly	Blood and pressure	Why blood pressure must be measured at heart level
5) Blood pressure monitor	Blood and pressure	How blood pressure monitors work
6) X-ray and fractures	Radiation exposure and medical imaging	History of the X-ray and modern application
7) 5G and radiation exposure	Radiation exposure and medical imaging	How dangerous is 5G?

8) Nuclear war and radiation exposure	Radiation exposure and medical imaging	What is radioactivity and when is it dangerous?
9) X-ray images and radiation exposure	Radiation exposure and medical imaging	How are X-rays taken and how high is the radiation exposure?
10) CT and radiation exposure	Radiation exposure and medical imaging	How does computer tomography work and how high is the radiation exposure?
11) Afraid of radiation?	Radiation exposure and medical imaging	How high is the radiation exposure in daily life?
12) Skateboarding and moment of inertia	Musculoskeletal apparatus and mechanics	Which tricks in skateboarding use moments of inertia?
13) Strength and climbing stairs	Musculoskeletal apparatus and mechanics	How high is your physical performance when climbing stairs?
14) Free fall and drop tower	Musculoskeletal apparatus and mechanics	How do air pressure and gravity interact during free fall?
15) Musculoskeletal system and back pain	Musculoskeletal apparatus and mechanics	Why do so many people have back pain in their lives and what can be done about it?
16) Arm muscles and lever laws	Musculoskeletal apparatus and mechanics	How to explain the anatomy of the arm muscles using the law of leverage
17) Bungee jumping	Musculoskeletal apparatus and mechanics	The law of energy and the law of springs applied to bungee jumping
18) Hearing loss	Acoustics and the ear	Everything that can lead to hearing loss
19) Volume and hearing	Acoustics and the ear	Why too much volume damages our hearing.
20) Frequencies and hearing	Acoustics and the ear	Which frequencies are damaged by noise trauma?
21) Frequencies and audible range	Acoustics and the ear	At what frequencies is the normal human hearing range?
22) Directional listening and “cosmophone	Acoustics and the ear	How do you localise a sound source and is there such a thing as sound in a room?
23) Doppler effect	Acoustics and the ear	How do you use the Doppler effect to determine velocities?

Closing The Circle

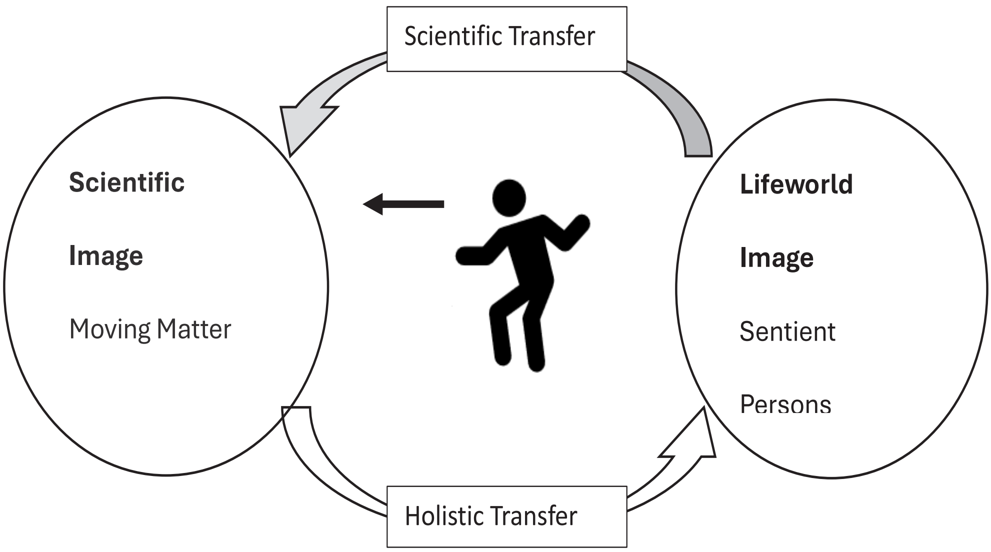
‘Closing the circle’ was a term that quickly became standard in the preparation and evaluation phase of the groups. Closing the circle meant looking at both images equally, the lifeworld image and the scientific image. Many groups began with a sequence of images from the lifeworld, then moved on to the scientific image and then returned to the lifeworld image.

Some groups started with the scientific image and then switched to the lifeworld image with the holistic eye. As a rule, these groups did not make a second switch back to the scientific image. As this only became apparent during the content analysis, it was not discussed in the course sessions. We therefore do not know the reasons for this asymmetry. We can only assume that the lifeworld image was a kind of reference point for these student teachers

The Role of the Teacher

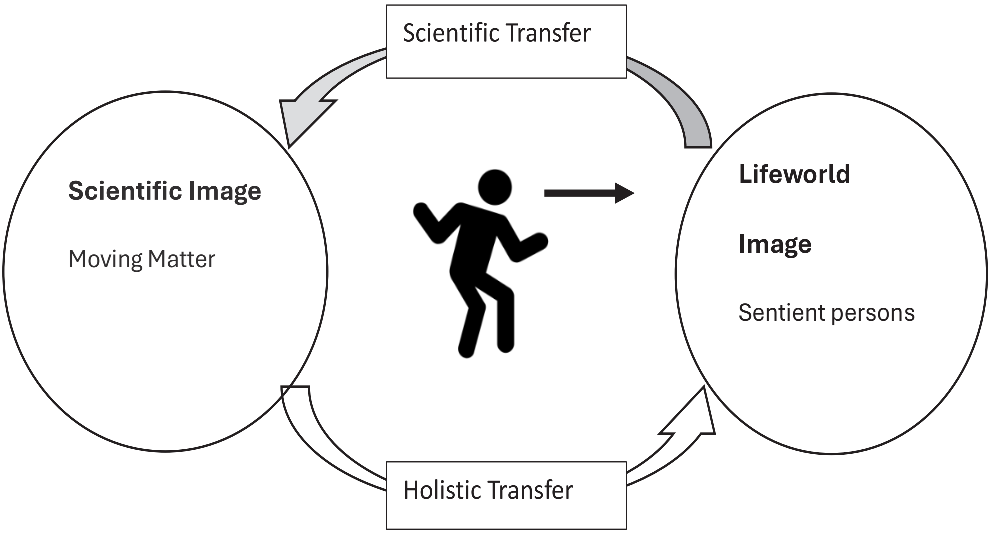
One of the most salient findings was that the Scientific Holism approach ('Two-Eyed Seeing') redefines the role of the teacher. In fact, the student teachers in their role as teachers had to switch between two different perspectives in all three phases of their miniature - preparation, implementation and assessment. In the scientific transfer (Figure 1), the student teachers (as teachers in the miniature) saw themselves in an expert role, i.e. their responsibility and identification lay with the scientific image. Figure 3 was used in the discussions to symbolise this situation. The teacher, the figure between the two images, points to the scientific image.

Figure 2. Scientific transfer: The teacher in the role of expert, with a focus on the scientific image, according to (Zeyer, 2022).



In contrast, in the case of holistic transfer, the teacher had a hermeneutic/empathic role because they had to engage with the lifeworld of their audience. Here, the students saw their role as a teacher as interpreting scientific facts and evidence in the light of the lifeworld and preferences of either their students or others, such as patients or environmentalists etc. Figure 4 proved helpful in symbolising this second role.

Figure 3: Holistic transfer: The teacher in the empathic-hermeneutic role, with a view to the life-world image, according to (Zeyer, 2022).



This dual role of the teacher (symbolised by the position in the middle between the two images) seems to be a rather new concept that, as far as we know, has never been described in the literature before. Indeed, switching between the two eyes to close the circle and the need for the teacher to switch between the two roles (expert and hermeneut) proved challenging but rewarding. It seems that our student teachers found the holistic transfer and the associated interpretive role of the teacher more challenging. Indeed, the expert role for a science teacher is more the conventional one and the student teachers had most likely experienced their own science teachers mostly in this role.

The transfer of the lifeworld image to the scientific image comes very close to the structure proposed by the classic concepts of scientific literacy (see introduction above). This is in line with the transition from the image of the world to the image of science, and scientific literacy in the sense of PISA means that everything that needs to be done has been done.

This concept may have unconsciously dominated the approach of the student teachers, who then assumed that the scientific transfer would in principle answer all the questions posed in the lifeworld picture. This may then have led to the holistic transfer only being perceived as a visualisation and application of scientific knowledge, based on the scientific image. Once this step has been completed, the circle seems to be closed immediately and no more questions seem to remain unanswered.

Indeed, a critical examination of the miniatures shows that many of them are simply examples of well-constructed contextualised science education. This is certainly a respectable outcome of an educational process, but it is not the kind of innovation that the present project was aiming for.

The pragmatic challenge for the student teachers was therefore to move away from the linear concept of context - explanation - prediction and to develop a true synoptic view of two complementary images. The results of this study show that this goal has not yet been fully achieved, but at the same time they have revealed some important complementarities that have proved helpful in the students' work towards this goal.

Orientation Towards Things and People

The complementarity of thing-orientation and person-orientation helped the students to better understand the ontological terminology of moving matter and sentient persons. It was derived from the literature on occupational research (e.g., Kuhn & Wolter, 2022). The idea of a dimension of things versus persons goes back at least to the 1960s. There is ample evidence that interest in STEM education and careers is strongly correlated with orientation towards things.

Interestingly, no coherent definition of things and people is given in the extensive literature on the subject, apparently on the assumption that the difference is clear. If there is a characterisation, it is usually based on the difference between inanimate things and living things. This leaves open, for example, the question of whether person is synonymous with living, or, another question, whether only humans can be persons, something the student teachers in the project discussed intensively.

Position and Sense Observations

The second complementarity that was helpful to understand moving matter and sentient persons was that between position observations and sense observations (Esfeld, 2020). The physical things in the scientific images of the miniatures were, for example, air molecules and their moving positions in an acoustic wave, or blood particles and their kinematic effect on the blood vessel wall, or mass particles in a skateboard and their rotation around the axis of symmetry. The biological things involved in the miniatures include the cilia and their positions on the ear, or the body collecting potential energy as the pupils run up the stairs, or various bones and muscles and their positional arrangement in the arm skeleton.

In the holistic transfer, these things had to be connected with the senses of the people involved. In the miniatures this was mainly through experiments, either physical or biological or both. Others were videos, student experiences, memories of certain scenes, etc., etc. But, of course, these sense experiences did not take place in a solipsistic vacuum, but within (different, sometimes overlapping) communities. The first and omnipresent community was of course the classroom, with the students, but also, and importantly, with the teachers. However, many other communities appeared in the miniatures, such as the teenagers (who listen to loud music), the skateboarders, the patients, the citizens, etc. etc.

Facts and Values

Another important complementarity in the alternation between the lifeworld images and the scientific image was that between facts and values, whereby values are used here in the broadest sense and include moral, social, political and aesthetic aspects as well as feminist and religious viewpoints, i.e. all areas that contain an evaluative aspect (Schroeder, 2021).

However, there was little discussion of values in the student teachers' miniatures. In most cases, instructions for action were derived directly from facts without embedding them in a concrete context. For example, from the illustration of hearing and the physical explanation of loudness, the conclusion was drawn that loud music should not be listened to. Or the miniature about thrombosis ended with the advice that you need to get enough exercise on long-haul flights. In moral philosophy, the tendency to infer directly from 'being' to 'ought' is known as the naturalistic fallacy (or, not quite identically, the is-ought fallacy). A reflective balance should always be negotiated between evidence-based principles and intuition-based value judgements (McGrath & McGrath, 2019).

Two-Eyed Seeing seems to be a way of introducing values and discussions of values beyond the scientific method into science lessons, thus avoiding the naturalistic fallacy. The critical moment is the holistic transfer, in which an interpretative element is essential. Scientific knowledge is important for decision-making, especially in health and environmental issues. But the holistic transfer between scientific knowledge, which is part of the scientific image, and value issues, which are part of the life-world picture, is the one that explicitly includes the freedom of thought, feelings, norms and actions of the people involved.

Facts and Sentiments

A characteristic of the observed lessons was that the lifeworld image was generally permeated by sentiments, a term defined by the Cambridge Dictionary as 'a thought, opinion, or idea based on a feeling about a situation or a way of thinking about a thing'.

In contrast, the change to the scientific image, the scientific transfer, often led to a noticeable drop in mood. For example, when a lesson on radioactivity began with references to the conflict in Ukraine, there was an anxious tension in the classroom. However, this tension dissipated when the focus shifted to the scientific explanation of physical radiation and was replaced by a more detached atmosphere.

This pattern was repeated in several lessons, including the lesson on blood pressure measurement, where the initial physical explanations of blood pressure left the atmosphere in the classroom cool and uninvolved. The emotional climate changed dramatically when the abstract scientific content was personalised by measuring the blood pressure of a student in the classroom who had an unusually high reading. This caused both excitement and concern.

It is significant that the teachers often avoided these emotional responses because they wanted to focus on the scientific content rather than explore its affective dimension.

However, the concept of Two-Eyed Seeing led to a frequent reconsideration of the importance of feelings in the assessment of lessons. Neglecting feelings was then seen as a failure: teachers missed the opportunity to respond to students' confusion and use these feelings to motivate scientific enquiry.

In our work with student teachers, we used the two terms fact-related and sentiment-laden to distinguish discourse in the science picture from discourse in the lifeworld picture. We used these terms to characterise discursive resources and took them from the recent results of an extensive language analysis (Scheffer et al., 2021) which showed that since the 1980s, the use of sentiment-laden words in Google Books has steadily increased, while the use of factual words has systematically decreased.

In our context, it is interesting to note that the authors provide about two dozen keywords for each cluster, e.g. mind, imagination, wisdom, wise, hunch, understanding, suspicion, believe, think, etc., for feelings-based discourse, and scientific, chemicals, model, method, fact, data, etc., for what they call fact-based discourse. A preliminary idea, yet to be tested, is to provide teachers with these discursive resources to help them create teaching materials for Two-Eyed Seeing.

Discussion and Conclusion

All in all, our study has shown that the scientific holism approach is a good way to better address health, environmental, and medical topics in science education than a conventional scientific literacy approach.

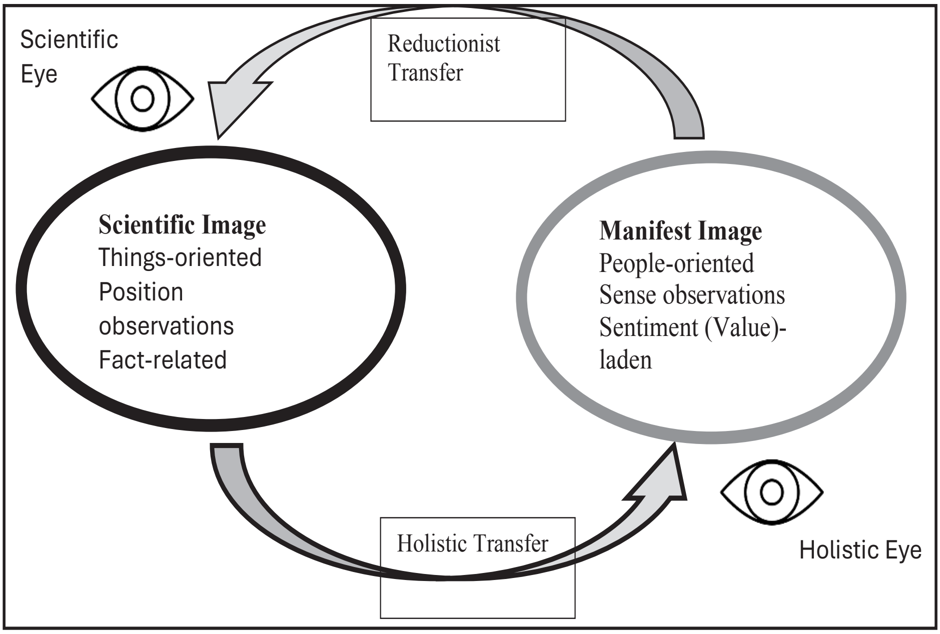
However, it also became clear that the new role of the teacher poses significant challenges, and the research process identified several ways in which teachers can be supported in managing the two transfer steps. Based on the considerations in the previous section, these aspects can be listed in complementary form, as shown in Table 1.

Table 1. Pedagogical complementarities that emerged from the research process (explanation in the text)

	Lifeworld image	Scientific mage
Ontology	things-oriented	person-oriented
Observation	position	sense
Reflection	facts	values
Discourse	Fact-related	Sentiment-laden

The idea is that teachers can use the contents of the table above to structure the two images in their lessons. Accordingly, Figure 1 also underwent considerable changes during the research process. From a philosophical point of view, these substitutions may be debatable, but they proved to be practicable, useful and stable during the teaching process. The instrument that emerged from this action research process is shown in Figure 4. We call it a pedagogical model of scientific holism and synoptic knowledge transfer ('Two-Eyed Seeing'). It should be understood as a pedagogical tool that emerged from the idiosyncratic context of our student teacher education. A different context might have led to a different model, but it is assumed that it would still have the basic features of the ontological model (Figure 1).

Figure 4: An educational model for scientific holism and synoptic knowledge transfer ('Two-Eyed Seeing'), as a result of the research process



Such models could also be used for environmental education and sustainability topics or, as mentioned at the beginning, as a general framework for the systematic integration of socio-scientific issues in the NSE. This requires further research.

However, the model certainly also has intrinsic didactic strengths because it simultaneously addresses person-orientated and thing-orientated learners and integrates affective, empathic and normative aspects into science lessons. It can therefore promote the motivation of all pupils, especially many girls, for science lessons (Zeyer & Dillon, 2019) and, at the same time, the idea of civic science education (Levy et al., 2021) is supported.

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UK Teachers' Knowledge, Attitudes, and Perceptions about Native Animal and Plant Species

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Biodiversity topics feature in UK primary and secondary science and geography curricula, providing a valuable opportunity for increasing children's ecological literacy. Studies in other countries have shown that teachers have poor species identification skills, but this topic has not been investigated for the UK. 90 primary and secondary geography and science teachers completed an online survey about knowledge and attitudes from 10/12/22 to 29/1/23. Recall (based on a free listing exercise) was highest for flowering plants, comparable for mammals and birds, and low for invertebrates and other vertebrate groups. Identification knowledge was highest for birds, comparable for mammals and flowering plants and low for invertebrates. There was a positive relationship between an individual's appreciation of nature and species knowledge. Respondents found colourful species attractive but species that could bite or sting unattractive. They believed that it was important for teachers to have identification skills and that children's identification knowledge was poor. I discuss the educational implications of the findings and effective interventions for increasing interest and awareness about plants and invertebrates with pre-service and in-service teachers.

Keywords: Species identification, biodiversity, invertebrates

Introduction

Children and young adults are increasingly becoming disconnected from nature in urban societies, due to less regular interactions with natural environments (Zylstra et al. 2014). Science and sustainability education provide opportunities for improving learners' ecological literacy, and biodiversity topics feature in primary (5-11) and secondary (11-18) science and geography curricula. Teachers' subject expertise should include species knowledge and identification, as an integral part of ecology, sustainability, and fieldwork (Skarstein & Skarstein 2020). The ability to identify species also increases learners' appreciation of nature. However, several studies found that teachers have poor identification skills, particularly for plants and invertebrates (Skarstein & Skarstein 2020). The antipathy for plants and invertebrates has been discussed elsewhere (Stagg and Dillon, 2022; Soga et al. 2020). The research questions for this study: (1) What are the comparative levels of knowledge and recall for different categories of plants and animals? (2) Is there a relationship between knowledge and nature connectedness? (3) What are teachers' attitudes and perceptions towards biodiversity?

Materials and Methods

The questionnaire comprised: (i) 4 demographic questions, (ii) free listing exercise (20 native plant and animal species), (iii) 6 Likert scale questions (nature-relatedness) (iv) identification test (6 plant, 6 mammal, 6 bird and 6 invertebrate species) (v) 6 Likert scale and 3 open questions (attitudes and perceptions). Free listing is effective for capturing differential awareness and recall for species groups (Gosling & Tilling, 2022). We used Nisbet and Zelenski's (2013) brief measure of nature relatedness, a robust and valid instrument for embedding into a questionnaire. The identification test comprised common native species that could be identified by novices from photographs, presented in random order. In the analysis, 2 marks was awarded for identification to species level and 1 mark for just family or genus. The online questionnaire was produced using Qualtrics (2022), piloted with 10 teacher educators, launched in December 2022 and publicized via social media.

Results

90 teachers participated in the survey: 36 secondary science (11-18) teachers, 21 secondary geography teachers, 18 primary (5-11) teachers and 15 'other' (e.g. technicians). Friedman ANOVA was used to test if the number of species specified per category in the free-listing exercise were drawn from populations with identical medians and the null hypothesis rejected ($p<0.001$, $n=90$). Most frequently listed groups were flowering plants (apart from grasses), followed by mammals and birds (Table 1). Friedman ANOVA was used to test whether identification test scores for the four categories were drawn from populations with identical medians and the null hypothesis rejected ($p<0.001$, $n=89$). Scores were highest for birds, comparable for mammals and forbs and lowest for invertebrates (Figure 1). The mean test result overall was 56%. Only 5% respondents correctly identified herb Robert, red deadnettle, common banded hoverfly and seven-spot ladybird to species level. There was a significant correlation between nature relatedness and species identification score, (Spearman's rank correlation coefficient, $p<0.001$, $n=90$) and Figure 2 shows a positive relationship. Species that respondents stated they would most like to learn about: badger, herb Robert and common shrew, whereas they were least interested in dandelion, woodpigeon, and daisy. Species considered the most attractive were robin, peacock butterfly, blue tit and least attractive were spider, wasp, and common nettle. Main sources of nature knowledge ($n=89$): family (61%), books/field guides (57%), hobbies (56%) and TV/video (47%). 56%

respondents thought it was important for teachers to have identification skills. 80% feel confident teaching identification skills. 70% respondents described children's identification skills as poor.

Table 1. Frequency of species names in free-listing exercise

Taxon	*Frequency*
Forbs (flowering plants except grasses)	738
Grasses, conifers, ferns, and bryophytes	41
Mammals	389
Birds	363
Reptiles, amphibians, and fish	107
Invertebrates	86

Figure 1. Identification accuracy.

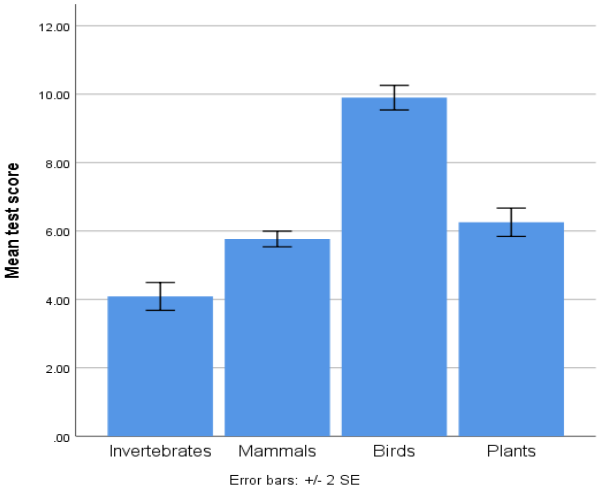
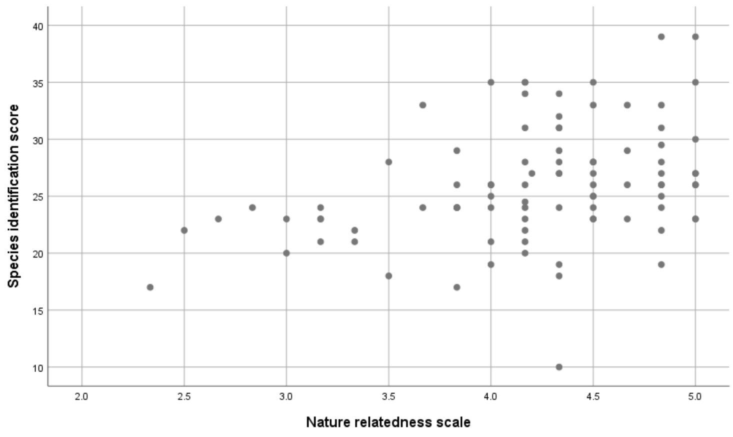


Figure 2. A comparison of nature relatedness and species identification.



Discussion

The results suggest that teachers' cognitive and affective bias against invertebrates is far greater than for plants, despite invertebrates being such a diverse group. Whilst the human bias against invertebrates is examined in the literature (Soga et al. 2020) it has received less attention than the established concept of low plant awareness (plant blindness). Like other studies, participants frequently failed to name plants and animals to species level (Gosler & Tilling, 2022). Family and hobbies were more important sources of knowledge than school and university, but respondents believed that species identification was important in schools. Most teachers felt confident teaching identification, suggesting that awareness about their gaps in knowledge was low. The positive relationship between nature connectedness and knowledge is not surprising, since interest in a well-known factor in cognition. Like other studies, the species considered the most attractive were colourful ones and least attractive those that could bite or sting. The low interest in daisy and dandelion is not surprising but does highlight a lost opportunity. These species are common in school grounds and offer high pedagogic potential for biology topics including tropic responses, asexual reproduction, adaptive behaviour, reproductive isolation and applied biology (Science and Plants for School, 2022). It is important to address these knowledge deficits and perceptions in pre-service and in-service teacher education since they are detrimental to learners' ecological literacy. Examples of effective interventions with pre-service teachers include the cultural use of plants for increasing interest (Yangin, 2019), foregrounding plants in education (Nyberg et al. 2019) and the role of gardens for observing invertebrates (Eugenio-Gozalbo & Ortega-Cubero, 2022). There was a significant increase in pre-service and qualified teachers' self-efficacy and pedagogic content knowledge, after attending webinars about "plant pedagogies" delivered by the lead author (n=48, unpublished data; webinar recordings available at https://bit.ly/42gwiLS).

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Strand 11

Informal, Non-formal and Out-of-school Science Education

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Foreword

The chapter Informal, Non-formal, and Out-of-school Science Education in the ESERA 2023 proceedings highlights the increasingly vital role that learning outside traditional classroom settings plays in shaping scientific understanding and engagement. In a rapidly evolving educational landscape, informal and non-formal learning environments—such as museums, science centers, community programs, and digital platforms—are gaining recognition for their unique contributions to fostering scientific literacy, curiosity, and lifelong learning.

The 11 proceedings in this chapter explore a broad spectrum of research focused on how these diverse contexts support science education. The studies presented here examine the methods, impacts, and innovative approaches that enhance learners' experiences in settings beyond the formal curriculum. They underscore the value of providing accessible, engaging, and contextually relevant science learning opportunities that meet learners where they are, whether through community-driven initiatives, outdoor education, or digital and media-rich environments.

Through this research, the authors demonstrate how informal and non-formal science education can complement and enrich formal schooling by offering flexible, learner-centered experiences. These contributions highlight the significance of out-of-school learning in promoting interest in science, nurturing scientific thinking, and broadening participation across different demographics and communities.

As you delve into the insights and findings in this chapter, we hope you are inspired by the innovative ways in which informal, non-formal, and out-of-school science education can be harnessed to engage diverse audiences. The research presented here reflects the ongoing commitment of educators and researchers to expanding the reach and impact of science education, ensuring that it remains accessible, relevant, and impactful for all.

Threading Natural and Cultural Heritage: A Case Study of a Science Museum Field Trip Plan

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Field trips can enhance student's life experience and motivate them to learn. Not all schools have access to a qualified heritage guide agency that can arrange educational field trips. This study explored how the National Museum of Natural Science (NMNS) in Taichung, Taiwan, acts as field trip collaborator to devise field trip plans with schools and domestic community organizations to promote elementary school students' awareness of the relationships between humans, nature, and conservation efforts while experiencing natural heritage. The NMNS sporadically holds fossil camps for students at a harbor-side outcrop fossil layer in Miaoli, Taiwan. A total of 18 elementary schools have participated this project. The schools expect that the NMNS can organize a field trip plan incorporating reflective thinking about humans and nature rather than offering a simple guided tour of the fossil layer. The present study applied the sociocultural approach to analyze the formulation of a field trip plan and determine how the museum collaborates with domestic community organizations to encourage the interpretation of local culture and natural heritage and how the museum cooperates with partner schools to refine the teaching plan of a field trip. From March 16 to May 11, 2021, 227 students from seven schools attended the aforementioned field trip. An analysis of students' post trip journals revealed that the students had deep impression about people in local community, matrix of wind turbine along the coast and offshore and the magnificent shell fossil outcrop. Only few students mentioned their awareness of the relationship between humans and nature. Following the participant schools' suggestion proposed revised plan: the coastal path guided tour was replaced with an on-site hands-on activity at a colonial-period abandoned tunnel and fossil outcrop. From students' post-trip group interviews and journals revealed that the students noticed the changes to the landscape made by past and contemporary people. Based on this case study, post practice reflections were discussed, and models relating to regional resources, science museums, and schools establishing sociocultural contexts and cross-disciplinary linkages in outdoor science education were proposed.

Keywords: Informal science teaching, marine and outdoor education, sociocultural theory

Research Background

At the end of 2019, the Taiwan Ministry of Education granted National Museum of Natural Science (NMNS) to propose an out-door field trip project for primary and secondary schools and offered it for schools to apply. The project aimed at bringing learning and reflective thinking focus about the relation between human and nature in the field trip. NMNS invited several partner schools engaging in project proposing. The Covid 19 is not yet outbreak in Taiwan, the consensus among schools was the field trip as an out-door activity and followed all Epidemic Prevention Regulations during the trip.

The Thread of Natural History

The NMNS sporadically holds fossil camps for students at a harbor-side outcrop fossil layer in Miaoli, Taiwan. The fossil layer is the evidence that the island of Taiwan rises from the ocean floor in 120 thousand years before and it was document since 1923, in a railway construction project during the Japanese colonial period. The colony governor assigned the fossil layer as a natural heritage and re-planned the rail track to protected it.

The Thread of Local History

There is a domestic festival Mazu Baishatun Pilgrimage to Beigang, the believers carry sedan chair with the Mazu idol on it on foot to walk 400KM to Beigang and came back to Baishatun every year since Japanese colonial period, and these years there always hundred thousand adherents participated the march on foot. The grand march might begin from the colony governor's propaganda that the spirit with incense burner of Mazu's parents located not just in the hometown of Mazu (coast village in Fujian Province, China), it had a stand in Mazu's Temple Beigang (Taiwan).

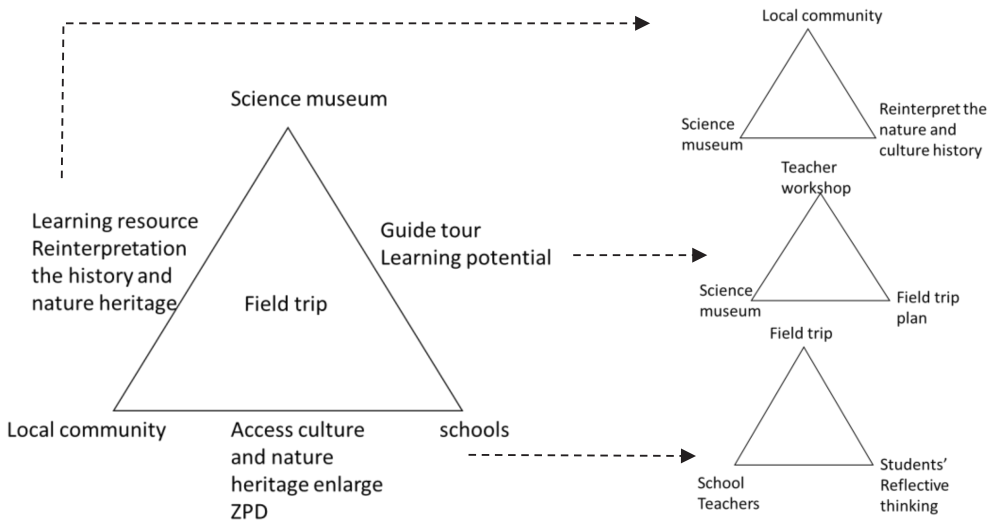
Domestic situation

The coastal line between fossil layer to Mazu Temple Baishatun is the first Onshore Wind Turbine Test Site in Taiwan, and the offshore will include in the business scale offshore wind turbine field. The nearby fishing village population are around 4000, average age is 63-year-old. Though there are not many fish boats keeping work regularly, there is a Coast Guard Branch office in charge of custom.

The framework of study

In this study, the activity theory as the basic framework to illustrate how science museum collaborate with schools and local community for the field trip.

Figure.1 Main framework of the study



The relation between science museum, school and community explored in this study show as the triangle in figure 1. Each side of the triangle represents two actors' relationship and the triangle pointed by the dotted line expresses the goal which they collaborate in the field trip. This study focuses on the process that science museum collaborated with teachers to design the activities for field trip through teacher workshop.

Teacher Workshop

During the research period, there were 6 teachers' workshops. Each workshop invited teachers whose classes will have the field trip on the same date. In the workshop, curator introduced the natural history and history background of the location. Then invited teachers to discuss how these natural history and historical information could relates to curriculum standards, what elements in the field trip could help them extending the experience for teaching in school, what are the possible extending learning activities that teachers would do after the field trip. The researcher summarized teachers' opinions for above questions and communicated possible learning activities in each learning sites or revising some parts. Research data came from the documentation of teachers' discussion in the workshop, the revised field trip plan and some teachers' after field trip feedback.

The Field Trip Plan

Original plan designed by museum curator which included two guided walks along the coastal hill path and two after visiting forums with community member. One guided walk introduced the discovery of fossil shell outcrop and learn about the geology of the island's birth, the other walk introduced folk botany and local wildlife investigating project.

Along the coastal path, the fossil shell outcrop was covered by plants and under your feet. Curator thought that walking on the path could help students to know how widely the fossil shell outcrop spreads, then introduced the folk botany and the citizen science project in the area to students.

The first-place students visited was the Mazu Baishatun Pilgrimage Museum, and one senior Mazu Baishatun Pilgrimage Preparatory Committee member interacted with students in the after-visit forum. The second-place students visited was local Coast Guard Branch office where students interacted with those officers.

The two places could be interpreted as “In an era of material poverty, people relied on their belief to Mazu to protect their lives at the seaside. In an era of rule of law and democracy, the coastal guard officer keep order for coast living people”.

Revised Field Trip Plan

Teachers suggested that the landscape along the coastal path could see lots of wind turbines. In the guided walk could introduce the technology about wind turbine, this can be the background knowledge for they teaching events about Sustainable Development Goals. Some teachers questioned the visit of Mazu Baishatun Pilgrimage Museum was “religious propaganda” and parents with different religious did not agreement.

The science museum communicated with local community members to collect more information about the wind turbine power field for guided walk and arranged wind turbine model making-testing activity for students learning wind power was not always steady. And curator communicate teachers’ concerns to docent of the Mazu Baishatun Pilgrimage Museum, we reach a consensus that all interaction with students base on the culture heritage introduction point of view, sharing personal experience and emotion, neither supernatural events nor religious propaganda talking.

Findings and Discussion

Teachers Preferred to Assign After Field Trip Journal as Their Extending Teaching

All teachers said they would assign after field trip journal as students home work. They thought that students could review their field trip experience through writing, and teachers could evaluate what events make students impressive from students’ writings, then teachers could prepare related material to teach further.

Students Admired Tour Guide of The Coastal Walk with Well-Knowledge And Felt The Sincerity of Docent of Mazu Baishatun Pilgrimage Museum

There were 6 of the ten teachers reported almost all students admired the tour guide of the coastal walk. Students mentioned in their journals: "the tour guide know a lot of plants and those plants' folk using", "the tour guide introduce all plants along the path", "he/she know the place thoroughly". There were 3 of the ten teachers reported that some students mentioned the docent of Mazu Baishatun Pilgrimage Museum in journals. Students felt the old man talking his experience of pilgrimage with sincerity, "he shared his respect and thank to Mazu". Teachers also that they felt their students had a happy time in coast guard office visit but students did not write much feelings toward these officers. Teacher said: "students described what they saw in the office and the experience of operating life-saving instruments", "not much students wrote how they think or feel about the officers who hosted them".

Teachers Suggest the Field Trip Need to Offer Some Task to Facilitate Students Aware the Fossils and Reflective Thinking Our Relation with Environment.

Some teachers reported that their students mentioned fossil layer and the wind turbines in landscape but few of their students described their feeling, value or reflective thinking. Teachers suggested to make learning sheets for the field trip, or assign specific task about reflective thinking or recording observation.

After Field Trip Teaching Plans: Computers Science, Science, Society

There were 3 teachers reported that they had further wind turbine inquiry in their science classes; two teachers reported their students making field trip journal on computer science courses; one teacher brought students discussion the benefit and disadvantage in society courses.

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School Science Clubs: A Glance of Teachers' Perceived Professional Development

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Learning is a dynamic process and learning to teach occurs across different contexts and is not limited to professional development courses. Therefore, it is necessary to explore what non-formal science contexts run by teachers, can bring to their professional development. This study attempts to provide insights to these issues through the context of school science clubs that are part of a network. The analysis of the current eight semi-structured interviews, conducted with mature teachers that run a science club, revealed that for them the participation in the club enhances their professional development at a personal, social and professional level. Since the science clubs are part of a network of school clubs there is a need to rethink how this network can improve science clubs to better contribute to the professional development of the participating teachers.

Keywords: Non-formal education, science clubs, teacher's professional development.

Introduction

Today, science teaching demands a greater connection between classroom and non-formal contexts because they provide students with the opportunity to develop learning in the cognitive, affective, physical, and behavioural domains (for example, King & Glackin, 2010). In fact, the number of studies analysing the effects of students' participation in non-formal science activities has increased considerably in recent years, showing that this type of event is a valuable addition to science education (Avraamidoo, 2015).

Teachers play a key role in this process, as they act as a bridge between both domains, formal and non-formal (Martín-García & Dies Álvarez, 2022). Therefore, it is now considered that learning to teach occurs across contexts and is not limited to school-based classrooms; thus, becoming an effective teacher practitioner requires experience in contexts beyond the limited confines of school-based classrooms (Anderson et al., 2006). However, little attention has been paid to the benefits of participation in non-formal activities on teachers' professional development (Avraamidoo, 2015). Teachers' professional development is here understood as their learning in three intertwined domains–personal, professional, and social–and considers human development and the development of self-identity (Simon & Campbell, 2012).

The bulk of the studies regarding science teachers' professional development in non-formal activities seem to have been carried out through the design and implementation of educational sequences that were part of a university course (Fernández-Oliveras & Oliveras, 2016) or an in-service teacher education program (Eren-Şişman et al., 2020). Moreover, the few known studies on are generally conducted in short-term activities, such as visits to museums (Çil et al., 2016), science centres (Eren-Şişman et al., 2020).

In contrast, long-term activities are much less studied, even though they are probably more conducive contexts for analysing teachers' professional development insofar as it is difficult for a one-off or isolated experience to generate major changes in the behaviour, attitudes, or beliefs of the teachers (García-Guerrero et al., 2019). In addition, even less is known on what the contribution of those long-term non-formal experiences, such as science clubs or science fairs, which take place at school and are led, organised, coordinated and developed by teachers themselves (Svendsen, 2016) is.

As a consequence, research in teachers' professional development in non-formal contexts is still not fully explored and the potential role that non-formal settings could play in teacher professional development has yet to be fully realized (Avraamidou, 2015; Gupta & Adams, 2012; Pickering et al., 2012). That being the case, in this article, we set out to explore how mature teachers, in charge of a school science club, perceive its contribution to their professional development.

We selected the context of school science clubs because they have proliferated in several countries (Davis et al., 2021),they are examples of long-term non-formal contexts in which teachers are in charge of the design and development of the activities, and little is known about their benefits to teachers' professional development (Behrendt, 2017), particularly to mature teachers who are deeply engaged in conceiving, designing, and running the clubs. Hence, science clubs are a particularly appropriate context in which to explore teachers' professional development and the benefits that teachers can derive from participating in non-formal science activities.

To approach our purpose, we employed Bell and Gilbert's (1996, 2004) model for teachers' professional development as a conceptual and analytical framework. This model is in agreement with Postholm (2012) perspective on teachers' professional development, as it considers that the development of the teacher as a whole person is key in the process of professional development because beyond cognitive factors, emotional and motivational aspects are also important in the professional development of teachers. Bell and Gilbert's model encompasses three levels:

1. Professional development involves both changing concepts and beliefs about science education and changing classroom activities. It may also involve learning some science, learning about science and the development of knowledge, beliefs and skills that are necessary to become a science teacher.
2. Personal development is associated with changing teachers' activities and beliefs about science education and reconstructing their own knowledge about being a science teacher.
3. Social development is the construction and critical acceptance by a teacher of acceptable ways of working with others, such as teachers, students, and parents.

Method

This study reports part of a larger investigation that analyzes experienced science teachers' subjective perceptions and experiences regarding school science clubs. These clubs belong to the "Rede Nacional de Clubes Ciência Viva na Escola" promoted by the Portuguese Ministry of Education, which aims to support the creation of science spaces in schools open to the whole school community. The network brings together a set of school science clubs spread across the country and counts with the collaboration of other institutions, such as universities, museums, and research centres (more information on https://clubes.cienciaviva.pt/).

To address this study's aims, we followed a qualitative approach. We focus on the lived experiences of mature science teachers in the specific context of running a science club in their school by highlighting the meaning of that engagement in their professional development.

Following Yang (2020) we considered experienced or mature teachers those who engaged in teachers' education degrees and that hold five years or more of classroom experience. Eight teachers were recruited according to their availability and interest. They all had experience as science teachers (>28 years) and in coordinating and running clubs (5-9 years). However, it is important to remark that none of the teachers had any pre-service or in-service training in non-formal science education practices.

According to approved ethical procedures, teachers were informed of the conditions and purposes of the study and asked to sign an informed consent form. Individual semi-structured interviews were conducted, audio-recorded, and transcribed verbatim. Open-ended questions were asked during the interviews. The analysis draws on Bell and Gilbert's (1996, 2004) model for teachers' professional development.

This framework (Bell & Gilbert, 1996, 2004) outlines the nature of teachers' learning in accordance with the types of professional development and provides a picture of what it means to be a science teacher and the dimensions on which their professional development should be based. Hence, data analysis based on this model provides hints on the learning that teachers value and the processes for achieving them.

Results

The interviews showed that teachers see participation in science clubs as an enriching experience, both professionally and personally, and, therefore, as an added value that contributes positively to their professional development. This contribution can be described in terms of the following three levels of Bell and Gilbert's (1996, 2004) model.

Professional Level

Teachers mentioned that the club provided opportunities to improve both their content knowledge and their pedagogical knowledge. Many themes covered in the club are beyond the science curriculum, interdisciplinary, and deal with hot topics in science which were not covered in their training courses, as T5 declared: "*Sometimes we also have to learn content that we didn't know about and sometimes try things we haven't worked on or studied much at university*".

In this sense, teachers see the club as an opportunity to expand their scientific knowledge. Furthermore, some teachers indicated that they were obliged to update their scientific knowledge in order to deal with them in the club, as T7 mentioned: "*it also forces me, from this point of view to study, to inform myself, to go after and seek other knowledge. This is also good for me (...) it also forces me to be constantly up to date*.". Therefore, the science club promotes self-directed learning that is highly appreciated by respondents:

> "In other words, [the club] also forces me, from that point of view to study, to inform myself, to go out, and seek other knowledge. That is good for me, too. I am not so limited; in other words, it also forces me to be constantly up to date." (T6).

> "For example, the programming and robotics workshop. When I obtained the materials, I had to know how they worked. I learnt, didn't I? So, I could work with them. That's it. I had to know how to assemble them, how to programme them. So, I learnt" (T8).

However, evolving at a professional level does not imply only self-directed learning; teachers also mentioned that they engage in professional training courses to seek support for the challenges that arise in the club, for example, engaging in a competition to simulate a real satellite:

> "We had meetings and training from time to time. National sharing meetings were also held. [...] But we have been in a lot of training, webinars, sharing …" (T3)

Concerning pedagogical knowledge, teachers mentioned two aspects: learning new methodologies and learning to articulate formal and non-formal contexts. In the former situation, the club demanded learner-centred approaches (e.g., project development or inverted classroom), which contrasts with those often used in the classroom. Hence, the club becomes a kind of "test tube" to experience new methodologies, which, in turn, migrate to their science classroom. This procedure is seen as a learning process.

> "[...] We are trying different things and, therefore, we know that there are things that already work, and maybe it gives us some confidence, more than trying it for the first time, because at the end of the day, our experiences were in the club, is it not? So, I think there is an effective exchange there [the club] give us some confidence, because instead of doing an experiment for the first time in class our first experiences are in the club" (T3)

Teachers also learned to articulate the club with the classroom; on some occasions, the club becomes a complement or an extension of the classroom that enables them to face some limitations they find in it, such as lack of time or practical activities. On other occasions, the club can be taken up again in the classroom as a starting point for addressing certain concepts.

> "Sometimes the time in the classroom is not enough and I end up using the club time as a supplement, [...] complementing the classroom work with the club work and vice versa." (T7)

Personal Development

Being in charge of the club required teachers to leave their "comfort zone" to perform tasks that are not usually accomplished in a science classroom. This resulted in reconceptualising what it meant to be a science teacher and their perspectives on education. As a result, teachers mentioned that their horizons as teachers were broaden "*moving from the person who has and transmits the knowledge to someone whose duty is to create learning opportunities and to guide and support the students*" (T7). Thus, the features of the club lead to a deconstruction of the characteristic role of the teacher, moving from the person who has and transmits the knowledge to someone whose duty is to create learning opportunities and to guide and support the students. This personal development is expressed with positive feelings towards teaching.

Indeed, teachers recognise that club activities give them the personal satisfaction of having done something different and beneficial for the children, even if it requires some effort and work. Therefore, these answers reveal the influence of club participation on teacher's affective domain as it contributes to increase their job motivation and promotes a change in their attitude towards teaching, as expressed by T6"*the club is also an opportunity to motivate myself"* and T7 "*deep down, I started to adhere to this kind [of projects] ... to motivate myself because, sometimes, the work of the classroom alone is a little routine, demotivating*".

Social Development

Social development was also mentioned by teachers, and it included teacher-student and teacher-teacher interactions. Regarding the first, teachers believe that the club encourages an alternative way of working and interacting with students. The more relaxed and less formal environment resulted in a closer pedagogical relationship, which allowed them to get to know their students better and promote the inclusion of students who are less participative. They indicate that because of this interaction, it is easier to understand students' interests, to uncover their scientific knowledge and perceptions, and to determine what difficulties they really have, what aspects they do not comprehend, and what aspects they have mastered and thus plan their teaching approaches accordingly. The following quotes are examples of teachers' perceptions of their relationships with the students in the club. The following examples illustrate these ideas.

> "It's closer, yes, it's more of a peer-to-peer relationship. [...] As it is closer, it is different; yes. [...] One of the aspects that I value is the pedagogical relationship, which is not easy to achieve in a class with many children, explaining it from this one-to-one relationship." (T5).

> "On the other hand, I also ended up having a better understanding of the interests of the children, and I can orient my classes in a way that interests them more because I know that this usually works out well, so I go that way. [...]Thus, it ends up giving you more flexibility and more ability to be in a class like the children and to be able to respond to their curiosity. (T4).

> "There have been certain students who have more difficulties (...) at the social level and at the study level and we try to bring them (...) and they engaged and liked it [the club] a lot; and they have already come to ask if they could come back again" (T1)

The teacher-teacher interaction was mentioned less, but some mentioned that the club provided opportunities to engage teachers working collaboratively. This entails dialogue with colleagues from other areas of knowledge to accomplish a project in the club which is simultaneously a school project.

> "I think that a large part of my preparation as a teacher has come through this, through my involvement in projects with other teachers, even from other schools (...), and my participation in these communities of practice. Deep down meant that I had learned a lot as a teacher and changed a lot of my attitude, my point of view as a professional." (T7)

Finally, in the interviews, teachers pointed out several factors present in science clubs that either favour or hinder their professional development. Among the former are, for example, establishing partnerships with other institutions or having to work in a way that differs from what is typical in classroom-based education, or the possibility of carrying out tasks or doing things different from those normally carried out in the classroom. Regarding the latter, teachers mentioned aspects such as school culture, teachers' workload, or lack of funding and disposable time.

> "I don't think the hours we have would be enough. With so few hours we end up not being able to go into much depth. We could possibly go into more depth and then we reach the point where 'ok, it's not going to work anymore. [...] I mean, it doesn't mean you can't do it, but it becomes more difficult." (T3).

> "Well, we have a problem here, another constraint, which I forgot to mention, is that unfortunately the following happens: [the Ministry gives money to the schools to run the clubs] while there is this money the clubs exist. When the money runs out, there's no funding for the clubs, which is normal because the schools don't have any money. So if the Ministry of Education doesn't intentionally give the schools money for the club, then there's no money and the clubs die. I've seen it and I live it and it's true." (T6).

Discussion

This paper focuses on experienced science teachers' perceptions of how the participation and coordination of their school science clubs contributes to their professional development. To do so, Bell and Gilbert's (1996, 2004) model for teacher professional development was chosen as the conceptual and analytical framework. Following these authors, there are two core purposes for any teacher development activity (Gilbert 2010); the first is described as becoming a more effective teacher, which means being better able to support students' learning, and the second focuses on improving teachers' motivation for their work and science teaching.

The results obtained in this study revealed how these two objectives are reflected in the responses of teachers participating in science clubs. Regarding teachers' effectiveness, the results provide evidence that, from the teachers' perspective, being in charge of a science club is impactful in terms of their learning and professional development, as they illustrate how participation in the club contributes to making them better professionals by addressing the three dimensions proposed by Bell and Gilbert (1996, 2004): personal, social, and professional. For example, teachers mentioned learning science content and a reconceptualization of the meaning of being a teacher but also an improved relationship with the students and the promotion of a greater collaboration with other colleagues.

Regarding the second objective, it is clear from the teacher's interviews that the club promotes motivation for their job and provides them with personal and job satisfaction. In this sense, Svendsen (2016) argues that to achieve effective professional development, it is not enough for teachers to develop new knowledge, but it is essential that teachers believe that the experience is meaningful and relevant to their teaching practice. In the case of the school clubs, the results show that the teachers who coordinate science clubs have this perception because, as noted above, they see the club activities as beneficial to the students and which is a source of great personal satisfaction for teachers.

Non-formal education has been acknowledged as a good door-opener to innovative and diverse approaches and materials which help to improve educators' preparation for teaching science (Affeldt et al., 2017). The results obtained in this study provide additional evidence that reinforces these conclusions as the science clubs seems to have provided the teachers with opportunities to test different teaching strategies and teach them to a new level by doing things differently from what they would normally do in a classroom. These opportunities may give them a greater flexibility in their teaching and with an increased knowledge of their students will allow them to provide their students with a more personalized and individualized teaching experience.

Finally, one last important aspect of the model is that it considers that within professional development there are two components that need to be addressed the input of new theoretical ideas and new teaching suggestions and the opportunity to evaluate and practice these new theoretical and teaching ideas (Bell & Gilbert, 1996). Based on the teachers' responses, it appears that the club can do both.. In this sense, it seems that the less constrained context of the science clubs, for example, in terms of time pressure or curriculum to be delivered, encourages teachers to to self-initiate an action-reflection cycle. In this cycle the science club can be seen as a kind of "test tube" where teachers explore new didactical approaches that may migrate to the classroom and where they can learn new content knowledge. As a result, teachers can (re)conceptualise their perspectives of what it meant to be science teachers.

Usually, traditional training just qualifies teachers to work in the school, in the formal education context (Pinto Monteiro al., 2016), so non-formal training is generally neglected when compared to training for the classroom. Moreover, in initial and in-service training in science teaching, aspects related to formal education are analysed (teaching units, materials and strategies, activities, etc.), but there is no reflection on the importance of relating all the learning that pupils obtain from non-formal sources to the programmes that are taught at the school (Guisasola & Morentin, 2007). In this context, the significance of this study is that it provides evidence that learning in non-formal science activities such as science clubs, complements the expertise and knowledge that science teachers have.

In addition, the results also provide some information regarding the challenges that teachers face when coordinating the club. These challenges suggest that to exploit the full potential of science clubs for teachers' professional development, it is important to change the culture of the school, opening it up to the outside world, but also to reduce the teaching load of teachers so that they can devote time to preparing activities and articulating them with the classroom (Pinto Monteiro al., 2016). Similarly, it seems necessary to establish a stronger network that allows the transfer of good practices between schools and promote budget allocations to cover the additional costs that these types of activities may entail. It would be important that teachers could have a voice about what are their learning needs and could receive feedback and continuous support on their progress.

Concluding Remarks

The overall focus of this article was to gather the perspectives and opinions of mature teachers who coordinate school science clubs in order to shed light on the conditions and features of the clubs that contributed to their professional development. This study reveals that mature teachers deeply engaged in running a school science club consider that it contributed to their professional development at the professional, social, and personal levels.

The results also provide insights into how to improve school science clubs' capacity to promote teachers' professional development. Teachers require increased collaboration and stronger partnerships with other community entities to access resources and opportunities that bridge scientific knowledge in real-life contexts. They would benefit from exchange programs that foster closer connections with other clubs, allowing for joint activities and mutual enrichment through the diverse expertise offered by each club.

Therefore, this article provides an evidence-based overview of the characteristics of clubs that support teachers' professional development in all three types considered in Bell and Gilbert's (1996, 2004) model. The features highlighted here can be used to guide not only the development of new school science clubs, but also the design of professional development programs that are responsive to teachers' needs and demands, as the key aspects identified provide a holistic perspective of what experienced science teachers value the most.

Finally, the findings of this study support the premise that science teachers' professional development is a complex process which is not possible to fully understand without considering the learning that teachers acquire in their daily practice during real-world teaching experiences. In some cases, it can be a consequence of brief and unplanned hallway conversations with colleagues, while in others, it is an instantaneous response or reaction to an action or observation that occurs while working. In other cases, it is a consequence of actions undertaken consciously with a clear formative intention, such as actively seeking opportunities to collaborate with peers or take part in workshops or courses. In any case, it is clear that, in one way or another, increasing the range of activities in which teachers are involved, providing them with new opportunities and new contexts in which to practise their profession, contributes to enhancing their professional development.

The question that remains is how a network of science clubs can take advantage of science clubs to better contribute to teachers' professional development. We suggest that schools, science clubs, and institutions that support them build collaborative agendas, as proposed by Dillon et al. (2016) in the context of Natural History Museums.

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School Science Clubs: What is Their Value for Teachers?

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This study aims at identifying the value that science teachers, responsible for these settings, attribute to science clubs. We present the data from a semi-structured interview with eight teachers. Data was analysed using Bell's framework, which was complemented with a bottom-up analysis of the data. Results suggest that teachers' value the clubs for students, which are consistent with Bell's framework, for the educational community, and for their professional development. They did not mention the value for the partner institutions. In summary, the clubs were seen as unique in terms of the opportunities they provide to "discover" science and reflect on its nature and its role in society.

Keywords: Non-formal education, educational value of science clubs, teachers' perspectives.

Introduction

Science is integrated into the everyday experiences of all members of society, including school-aged students. These students come into contact with science not only in school but also in many other moments or aspects of their daily lives, from watching a sunset to visiting a museum in their leisure time. In this context, non-formal science activities are becoming important contexts for promoting children's engagement with science (Burke & Navas Iannini, 2021) because they provide a series of learning opportunities that add value to science education. For example, it appears that these spaces have the potential to address aspects that cannot be fully developed in the classroom (Jarvis and Pell, 2005) as they offer students the necessary time and space to engage in collaborative and open-ended projects without the constraints of a structured school curriculum (Sahin et al., 2014).

Researchers such as Fallik et al. (2013) or Hofstein and Rosenfeld (1996) emphasise the importance of constructing bridges between non-formal education and school-based science, aiming to foster synergies and advance a more comprehensive integration between these two domains. This suggests the need to create a cohesive educational framework that facilitates the flow of knowledge and experiences between the formal and non-formal science education sectors, aligning their objectives for a more harmonious learning experience.

These collaborations are significantly more straightforward to establish when there is the potential for an ongoing exchange of experiences between formal and non-formal educational settings. Additionally, when the connection extends over a long period of time rather than being limited to a single visit to a non-formal environment, it fosters a more enduring and productive partnership. Moreover, it provides ample opportunities for co-planning and co-implementing science activities that are both complementary and relevant to students' overall education (Bevan et al., 2010; Watermeyer, 2015). School science clubs are long-term projects that can extend and complement the school curriculum, such as science clubs.

Nevertheless, within these collaborative partnerships, an underlying curriculum, whether implicit or explicit, often takes shape to address the objectives and priorities of the collaborating institutions (Bell et al., 2009). The value of science clubs has been studied primarily in terms of their impact on students (Behrendt, 2017), but little is known about their potential educational value for those involved in them. Given the indispensable role that teachers play in overseeing and administering school science clubs, it becomes essential to delve into the depth of their appreciation and understanding of these initiatives. The role of teachers in shaping the educational experiences of students is pivotal. Their prioritization of specific pedagogical objectives significantly influences their approach to these clubs, their interaction with the club's participants, and the ultimate outcomes derived from these extracurricular undertakings (Behrendt, 2017; Karnezou et al.,2021).

Therefore, the aim of this study is to describe teachers' beliefs about the value of the science clubs. These beliefs are a powerful way to disclose how they conceive them for, what are unique in them, and provide insights on what they want them to become. Such insights into teachers' beliefs and aspirations offer a powerful lens through which we can gain a profound understanding of the underlying motivations that drive the success and effectiveness of science clubs.

Method

This study is part of a larger research project that explores how experienced science teachers perceive and engage with school science clubs. These clubs are part of the "Rede Nacional de Clubes Ciência Viva na Escola", a program supported by the Portuguese Ministry of Education, aimed at creating science spaces in schools that are accessible to the entire school community. This network includes various school science clubs across the country and involves collaboration with institutions like research centres, universities, and museums.

This study can be classified as a descriptive qualitative investigation because our primary aim was to give participants the opportunity to express their thoughts and experiences fully, allowing a detailed account of their unique perspectives (Merriam & Tisdell, 2015). This approach allowed for an in-depth exploration of the experiences and perspectives of experienced science educators who are actively engaged in coordinating their school science clubs.

Headteachers from over 70 schools in northern Portugal were contacted, and they, in turn, extended invitations to teachers responsible for running science clubs within their schools. Then, eight participants were carefully selected for this study, a process guided by their availability and a demonstrated interest in the research. They were highly experienced professionals with more than two decades of teaching experience and each of them was actively serving as the coordinator of their school's science club.

In line with ethical standards, teachers were apprised of the study's objectives and conditions and were requested to provide their informed consent. This process aimed to ensure that participants had a clear understanding of the research's purpose and were willing to take part. Individual semi-structured interviews were carried out, during which the conversations were recorded and transcribed verbatim. These interviews incorporated open-ended questions, allowing participants to express their thoughts and experiences openly.

The data analysis was conducted by referencing Bell's (2009) "strands of science learning" framework. This framework was further complemented with other categories that naturally emerged during a bottom-up data analysis, namely reconceptualize the value of informal learning contexts, promoting educational community's science capital and promoting teachers' professional development. Bell's (2009) framework is predicated on the idea of overlapping learning in formal and informal settings. It was designed to "capture the multifaceted nature of science learning" and is an extension of the National Research Council four-strand model developed to define the essence of science learning (National Research Council, 2007). The model incorporates two additional strands that focus on the distinct characteristics of non-formal or informal environments, thus providing a comprehensive framework for understanding elements of scientific knowledge and practice. These six learning strands are described as follows (Bell et al., 2009):

- Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.
- Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.
- Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.

- Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.
- Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.
- Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

The different strands are closely interconnected, with progress in one strand promoting progress in the others. They offer a valuable framework to assist educators, exhibit designers, and other practitioners in the informal science education community in articulating learning outcomes as they develop programs, activities, exhibits, and events (National Research Council, 2010).

Results

Teachers mentioned several values for the club, with a primary focus on students, while some values also extend to the broader educational community and teachers themselves. When considering students, teachers identified various values associated with the club, many of which were closely aligned with the school curriculum. These values encompass the multifaceted nature of science learning and are aligned with all six strands described in Bell's (2009) framework, which appear interconnected in the teachers' responses.

Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world. (Strand 1).

Teachers pointed out that science club is important to motivate students, to stimulate their curiosity and interest in science, their desire to learn and to know more but also to engage them in scientific activities and to develop a certain taste for science that will encourage them to continue studying science at school and university.

> "Deepen their interest in science....to have the will to explore, to do and to awaken interest in scientific areas as well." (T5).

> "what we want is to motivate students towards science [...] we want to develop an interest in science and motivation for science [...] at least I think that's the main aim is to promote a taste for science [...] we're very concerned with motivation, with interest [...] with their desire to always know more, to try to understand how everything around us works and to try to get them to observe." (T2).

Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science. (Strand 2).

Teachers value the science club as a mean to promote students' understanding science ideas, clarifying certain concepts, and working on some curricular content (T6). For instance, T7 highlights how the club enables her to "*establish a link with the curriculum, that is, to articulate what is done in the classroom and what is done in the club*". Similarly, T2 views the club as an avenue to "*try to consolidate a bit of the scientific knowledge they are acquiring, which is not very vast either*".

> "knowledge and contents are essential [...] to acquire the contents, to learn them through emotions and through the cognitive part [...]" (T6).

Nevertheless, the science club is not solely perceived as a supplementary resource for supporting in-class science instruction; it also serves as a platform for expanding the curriculum and delving deeper into scientific topics. As noted by T5, "*[club's activities] help to deepen curriculum topics [...]*".

In this regard, one of the aspects highly valued by teachers is that the club allows them to reinforce or address challenging topics and content that students may struggle to comprehend. As highlighted by T6, "*I selected themes where I noticed that students had gaps, and so the activities are tailored to those themes, focusing on essential learning that I know they require. The goal is to acquire the content and learn it through emotions and the cognitive aspect.*"

Additionally, for educators like T5, the most intriguing aspect of the club lies in its potential to facilitate conceptual change:

> "Sometimes in the classes it can happen that the children don't have so much opportunity or so much time to think, to change their conceptions of the world, their preconceived ideas [which are] something not very scientific, but that is there. So, in order for that change to take place, sometimes a process of reflection is necessary, and the club provides that [time]". (T5).

Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world. (Strand 3).

Engaging in experimental work within the context of science clubs allows students to interact with the fundamental elements of scientific inquiry, which in turn fosters the development of various skills (see T5), particularly when the experimental work is linked to the curriculum. Science clubs provide students with an opportunity to do science and to reflect on their own scientific conceptions and knowledge. The clubs enable students to not only perform scientific practices but also personally experience the experimental dimension of science, putting into practice some of the key aspects of scientific methodology.

> "We do try to get the kids to do experiments in the club which are related to curricular topics. [We try to] work on the experimental component of science [...]. the main objective is for the children to experiment [to promote] the children's ability to experiment, to manipulate and to think about what is happening." (T5).

Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena (Stand 4).

The club is seen as a means to promote students' awareness of what science is, its nature and how scientific knowledge is generated (see T7). Furthermore, some educators perceive the club as an instrumental resource for fostering scientific literacy and cultivating a scientific culture among their students, as emphasized by T8.

> "That is, if we want them to have epistemic practices, that is, science practices; they have to communicate science as a scientist, which include present their work in a congress and is validated by the community." (T7).

> "To raise awareness of what science is [...] and try to realise that the whole world works through science and that their lives are directly linked to science" (T2).

> "Increase the scientific culture of the students [...] In particular, invest in increasing scientific literacy [...] To increase their literacy a little this year too:" (T8).

Teachers acknowledge that the science club offers students a unique opportunity for self-reflection and a deeper understanding of their individual learning processes. However, as it was described for strand 2 (see T5), this requires time, which often does not exist in the classroom. The distinctive value of the club lies in its capacity to provide this essential time, enabling students to engage in meaningful self-reflection and self-assessment.

Participate in scientific activities and learning practices with others, using scientific language and tools. (Strand 5).

Strand 5 focuses on how learners come to appreciate how scientists communicate in the context of their work as well as building learners' own mastery of the language, tools, and norms of science as they participate in science-related inquiry (Bell et al., 2009). For some of the teachers the club is a vehicle for engaging students in science communication, within the club to in public events

(T7) but it a value that was little mentioned by teachers.

> "[…] they get involved in projects… this allows them to develop competencies which they do not develop in the classroom.... if we want them to have epistemic practices, that is, science practices; they have to communicate science as a scientist, which include present their work in a congress." (T7).

Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science (Strand 6).

The long-term nature of the club makes teachers believe that it can support students' development of an identity as someone who knows about and uses science. Teachers value the clubs as a means of demonstrating to students that science is essential to society and plays a key role in their daily lives and thus that the science, they learn at school will be important in their lives to understand the world around them.

> "That they don't feel that [science] [...] has nothing to do with their life. It's making it present and making them feel that what they learn has an important content in the life they have." (T1).

The different elements of Bell et al.'s model (2009) appear heterogeneously distributed in the teachers' responses (Table 1). In this context, while Strand 6 is mentioned most frequently, as it appears in the interviews of up to seven of the eight teachers, Strand 5 is mentioned the least, appearing in only two of the interviews. The remaining strands are mentioned by four teachers (Strands 2 and 3) or five teachers (Strands 1 and 4) of the participating teachers.

Table 1. Values attributed to the science club by teachers. Teachers that mention each of the six strands in Bell et al.'s framework (2009).

Value for the students	Teachers
Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world. (Strand 1).	T2, T3, T4, T5, T7
Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science. (Strand 2).	T2, T5, T6, T7
Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world. (Strand 3).	T1, T5, T7, T8
Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena (Stand 4).	T1, T5, T6, T7, T8
Participate in scientific activities and learning practices with others, using scientific language and tools. (Strand 5).	T3, T7

Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science (Strand 6).	T1, T2, T3, T4, T6, T7, T8

However, beyond the aforementioned factors, there are several other characteristics of the science clubs that teachers perceive as valuable from their perspective.

Reconceptualize the Value of Informal Learning Contexts

As club members, students become increasingly aware of the club's significance as a valuable learning resource, enhancing their appreciation for studying science beyond the classroom. Additionally, both fellow teachers and the broader educational community start recognizing the worth of the club's activities as a source of scientific knowledge and skills, motivation and enjoyment.

> "engaging in clubs […] enable them to enhance their skills, their learning. [Perceiving] that it is not a kind of leisure activity, without major goals [...] acknowledge the importance of this type of initiatives: the club. Those of us in science have already realised, or are realising, the importance of this kind of initiative, this kind of club. [The school and the community] they end up realising, in other words, that work is done there informally, but that it's serious work and that it leads to results that are recognised." (T7).

Promoting Educational Community's Science Capital

The club aims to be a space where participants can meet science and a place where they can see science in a different, much closer way but also a space to disseminate the study of science to as many people as possible, involving the whole community. This issue can indirectly favour students. In this sense, some activities in the clubs seem to be designed to publicise what students do in the club and to show their projects to their parents and the community so they can see the relevance of what is being done in the club.

> "I believe that initially the project [the club] aims to develop scientific literacy not only in students, but also in parents and the community" (T2).

> "The main goal of the club is to spread science, is to show the kids, and society in general, to my colleagues, to the educational community, that science is essential to make informed decisions" (T6).

> "Then publicise the study of science to as many people as possible. Not just the students, but also the rest of the school community. Because if we can make parents realise that this is important, it will probably be reinforced at home." (T8).

Promoting Teachers' Professional Development

While clubs were not conceived with the main aim of promoting teachers' professional development, all teachers mentioned that these projects promoted their personal social and pedagogical grow:

> "we come into contact with some things that we didn't know, we learn and we also improve [as teachers] That training is a bit of a win-win for us too" (T3).

> "I think that my training as a teacher has been very much based on this, on my involvement in projects [such as the club]" (T7)

Discussion

In this study, the perceptions of teachers who coordinate science clubs were analysed to obtain insights into the educational value they find in these activities and to understand what they value most about the clubs. Understanding teachers' perceptions is essential in harnessing the full potential of science clubs for both students and the broader educational community.

Teachers recognize various educational values in the club, with the majority of them being related to students' learning and aligning with Bell's (2009) six strands framework. These clubs are not only valuable for enhancing students' understanding of science but also provide a unique platform for students to engage with various facets of scientific knowledge. Furthermore, the teachers' perspectives offer valuable insights into the broader significance of science clubs in promoting scientific literacy and cultivating a scientific culture within the student community.

The most frequently mentioned strand is Strand 6, closely followed by strands 4 and 1. This may imply that the elements related to the nature of science and scientific inquiry are strongly associated with the activities that teachers actively promote in the science club. On the contrary, strands 2 and 3 received fewer mentions, and strand 5 was the least frequently discussed. On the contrary, strands 2 and 3 received fewer mentions, and strand 5 was the least frequently discussed. This pattern might suggest that teachers perceive the development of an understanding of science concepts (strand 2) as an achievable outcome within the club, but perhaps they undervalue it in comparison to other aspects, such as skills and attitudes, which can be challenging to foster in the classroom due to constraints like limited time or an extensive student body (as highlighted by T3).

"I think the sciences in the curriculum are becoming very theoretical and that's a shame. In my day it wasn't like that, I had much more practice than theory. In other words, theory came as an explanation of practice and almost not the other way round. I think, perhaps in my utopia, that's what the club is - bringing back that practice that no longer exists and that the students don't even know about, so they can't say whether they like it or not because they don't even know about it. I think the club ends up being more of a response to my need for things that I can't do in the classroom, due to the number of pupils I have or the little time I have, and I have my outlet in the club to be able to do those things that I'd like to do in the classroom and can't" (T3).

In exploring this further, it appears that teachers place greater importance on the club providing an opportunity to comprehend how scientific knowledge is constructed and what science entails than on merely enabling the consolidation or acquisition of specific scientific concepts. Hence, it becomes evident that teachers are particularly inclined to prioritize the experiential and practical dimensions of science learning in the club setting. They believe that such activities provide students with unique opportunities to engage deeply with the nature of science and scientific inquiry. Moreover, it indicates that teachers might value the science club as a space where they can present science as something you put into practice and not just something you learn about.

As for strand 5, teachers may believe that fostering teamwork is something achievable within the traditional classroom environment, and consequently, they do not perceive the club as particularly distinctive in this regard. However, they do seem to appreciate the club as an opportunity for students to become acquainted with the language of science and develop the skills necessary to communicate it to others in various contexts.

Regarding Strand 6 it is linked to how individuals perceive themselves as learners of science and how they nurture an identity as someone who possesses knowledge of, engages with, and occasionally contributes to the field of science. In other words, it addresses how learners view themselves with respect to science. Therefore, a common term which is commonly associated with Strand 6 is the idea of scientific identity, which typically refers to a person's concept of themselves as a potential scientist.

For instance, taking into consideration the work by Burke and Navas Iannini (2021), the cultivation or reinforcement of a scientific identity is identified as one of the outcomes of participating in a science club. In fact, their findings underline the club's role in shaping students' scientific identity. However, in contrast to their findings, Portuguese teachers in the present study do not explicitly emphasize the club's role in fostering a scientific identity in students. Instead, it seems that they place greater importance on students perceiving science as a cultural manifestation, an integral component of their culture, and one of the most significant factors in society, with clear and practical utility in everyday life. This takes precedence over the students acquiring a scientific identity that positions them as a science person. Nevertheless, it is evident that, in one way or another, science clubs serve as a mechanism for students to connect with and identify with the scientific enterprise.

This perspective aligns with the idea that the club not only imparts scientific knowledge but also situates science within a cultural and societal context. It underscores the idea that science is not an isolated discipline but an integral part of our collective culture and daily lives. Consequently, the club is instrumental in conveying that science is not solely confined to laboratories and academic settings but is intertwined with our culture and influences our daily experiences. This broader understanding of science's cultural and societal relevance can be seen as a crucial outcome of participating in science clubs. It empowers students to perceive science as an essential and accessible part of their world, encouraging them to engage with it as active participants rather than distant observers. This, in essence, represents a distinctive dimension of the club's impact on students, aligning with the broader cultural and societal context of science.

Strand 1 aligns with one of the fundamental characteristics of non-formal education: its capacity to enhance students' motivation and interest in scientific disciplines (Affeldt et al., 2017; Carver et al., 2021). A key aspect within this strand underscores the significance of harnessing students' prior experiences and interests as key elements for promoting motivation and interest. In this regard, science clubs offer a distinct advantage in allowing students to delve into topics that genuinely raises their interest (T1 and T3). This aspect could be one of the primary reasons explaining the motivating effect of science clubs (Vartianen & Aksela, 2013) and substantiates why educators place such value on these initiatives.

> "The students occasionally suggest ideas about it... in the workshops... in the weekly workshops it's the kids who define what they want to do. When it's the weekly workshop, they usually choose and say what they want. Normally with secondary school, we try to create a project that is of interest to them and with primary school activities it's normally the kids who say what they're interested in" (T1).

> "They usually choose the themes, so they're the ones who come up with the problems and then we work on the basis of the problems they've raised." (T3).

The club is also perceived as a valuable resource to reshape students' perspectives on the avenues for learning science, extending far beyond the confines of the classroom. This notion embodies the concept of lifelong learning, emphasizing that there is no solitary path to acquiring scientific knowledge. Consequently, these findings imply that educators are open to fostering increased collaboration between formal and non-formal educational domains, facilitating shared initiatives and collaborative projects. In this context, science clubs serve as a bridge that connects traditional classroom learning with extracurricular non-formal educational experiences. The teachers recognise that the value of the club extends beyond its potential benefits for students – it holds significance for the educational community and even for their own professional development. In fact, educators regard the club as a highly valuable personal and social experience, providing an added dimension that enhances their professional, personal, and social growth. The recognition that the value of science clubs transcends the students' experience underscores their broader significance within the educational landscape.

Analysing how this professional development occurs within the club, which club elements foster this growth, and the potential long-term effects on teachers' pedagogy opens up a new avenue for continued research regarding the contribution of school science clubs to science education. While much of the focus has traditionally been on the impact of science clubs on students, the emerging perspective emphasizes that these extracurricular initiatives offer a two-fold educational benefit. Not only do they enrich the students' learning experiences, but they also serve as a platform for teachers to continually develop their pedagogical skills and understanding of effective science education. The fact that teachers, recognise that the value of the club goes beyond its potentialities for students – it is of value for the educational community and even for their professional development (Davis et al., 2021) – suggests the need to explore these potentialities by engaging partners. Finally, teachers did not mention the value of the clubs for their partners, which seems to be an aspect to explore in order to build a common agenda between school and institutions that take the best advantage of clubs to those involved in them. These findings highlight the potential for enhanced collaboration among educational stakeholders to unlock the full range of benefits that science clubs can offer, further enriching science education and strengthening the connections between formal and non-formal learning environments.

Conclusions

Teachers recognize several values into the clubs and their uniqueness in addressing science learning. The results provide further evidence of how the purposes, objectives, benefits, and utilities of the school and non-formal education contexts align and complement each other, showcasing the possibilities that shared initiatives between both domains can offer. In this regard, non-formal spaces can play a key supportive role in the progression of learning, especially when it comes to long-term and non-sporadic activities. In this sense, the clubs, as long-term activities, have a primary advantage as they enable teachers to link club activities with what they are teaching in class, thus facilitating the learning process. This synergy between formal and non-formal education can have a significant impact on student development. By allowing teachers to connect club activities with the school curriculum, a bridge is created between these two learning environments. Students can see how what they learn in the classroom directly relates to the activities they engage in at the science club. This can increase their motivation and their understanding of the relevance of science in their everyday lives. Ultimately, this connection between formal and non-formal education can enrich students' learning experiences and promote a greater interest in science. Hence, these results can be the departing point to discuss a collaborative agenda between the institutions involved in the network of clubs. This agenda can include the design of successful programs for students and educational community, aligned with the educational projects of the schools and the institutions that are their partners, as well as supporting teachers' professional development.

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Which Teachers Visit Out-Of-School Learning Environments?

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Visits to out-of-school learning environments (OSLE) are becoming increasingly popular. Due to their diversity, they offer very different supplements to the classroom - like deepening knowledge, gaining practical experience, or building stronger connections to the everyday world. In this study, we investigate which teachers visit OSLE in Germany, what influences their visiting behavior, and how much time they use for preparatory and follow-up lessons. It is found that teacher characteristics such as age, experience, or gender do not influence behavior. The subject taught and especially the number of subjects taught, on the other hand, have a clear influence on the frequency of visits and the choice of learning venue. The time spent on preparation and follow-up after the visits varies greatly for the different learning sites. However, since integration into the school lessons is key to OSL sustainability, it is an important factor to look at.

Keywords: Out-of-school sites, teachers, visit behavior

Introduction

Out-of-school, or non-formal learning environments (following the characterization of Eshach, 2017), are places that are usually visited by students in class grouping and are located outside of school. Typically, these are student laboratories, museums, science centers, and zoos, but also industrial plants, farms, or places in nature. The range of out-of-school learning opportunities is vast, and the motivations for teachers to visit such places vary accordingly. What all OSLE have in common is a generally high motivational potential for students (Guderian & Priemer, 2008, Yildirim, 2020). The goal of a visit is usually not primarily the acquisition of new knowledge but rather the consolidation and integration of knowledge that has already been acquired in the classroom. The focus is on differentiating and deepening knowledge (Falk & Dierking, 1998), the practical application of what has been learned in a realistic environment (e.g., student laboratory), or the creation of everyday connections or historical references (e.g., in museums). Particularly with regard to the natural sciences, it is also a goal, in the sense of strengthening scientific literacy, to form one's own (science-related) attitudes and subsequently be able to make better and evidence-based decisions (Schiepe-Tiska et al., 2013). There is little empirical evidence on the attendance behavior of teachers and their classes at OSLE, especially in German-speaking countries. This is due, on the one hand, to the strong fragmentation of educational systems and, on the other hand, to the great variety of OSLE. Both of these factors make it difficult to obtain an overview. With this study, we want to offer insights into visiting behavior, analyzing the field from the perspective of teachers. The central questions of the study are:

- Which teachers attend out-of-school learning sites?
- What types of out-of-school learning sites are attended?
- How much time do teachers spend on the preparatory and follow-up work with students?

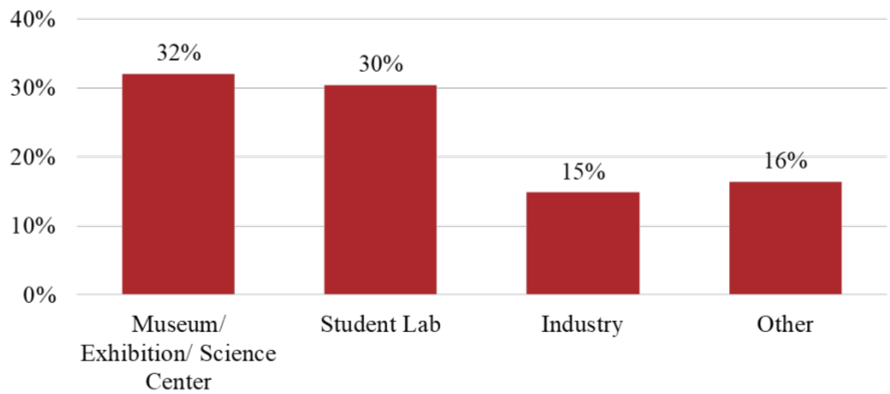
The last question works as an indicator for the sustainability of the OSLE visit: In principle, OSLE have a high motivational potential, which is a favorable prerequisite for successful learning (Erhorn & Schwier, 2016). Thorough preparation and follow-up of the visit to the OSLE is an important influencing factor, not only for the motivational effect of a visit (Geyer 2008) but also for increasing the interest of the pupils (Glowinski & Bayrhuber, 2011; Itzek-Greulich et al., 2014; Itzek-Greulich et al., 2016). With regard to the acquisition of knowledge at extracurricular learning sites, it is more difficult to provide evidence, as the main question is which learning intention prevails at the learning venue: at school, the learning intention is typically strongly focused on the acquisition and structuring of new knowledge, while extracurricular learning venues tend to serve the consolidation and integration of existing knowledge, with a focus on deepening, differentiating and refining what has been learned (Falk & Dierking, 1998), which is much more difficult to measure. Research results by Lewalter (2016) show that museum visits as one-day field trips detached from lessons are hardly effective but that systematic embedding in lessons is essential in order to achieve positive effects in terms of both learning growth and motivation. Reimann et al. (2020) were able to show a similar effect for learning gains during school laboratory visits, where a "long-term effect" could still be demonstrated after 12 weeks. However, there are multiple ways of connecting OSLE with school teaching using different (analog and digital) media. A systematic overview of connection possibilities can be found in Kampschulte (2018), whereas a study on media offered by OSLE in Germany can be found in Kampschulte et al. (2019). This study provides information on how much time teachers spend on organizing the trip and preparing the content – both for themselves and in the classroom.

Method and Sample

For the study, teachers from 14 German states were surveyed anonymously with regard to their use of OSLE and some personal variables. Both paper-pencil and online questionnaires were used. A part of the sample was acquired at teacher conferences, and a second part via mailings. The sample comprised 366 valid questionnaires of STEM teachers. Relations between different variables were analyzed using cross-tabulations and Pearson's Chi-Square Test as well as the Likelihood-Ratio Test.

The participating teachers were predominantly employed at public schools with upper-secondary level (63% Gymnasium/grammar school track, 27% Gesamtschule/common track); other school types were represented only in small numbers (10%). A mixed picture emerged regarding professional experience. Teachers with little (0-5 years; 19%) and moderate experience (6-10 years; 23%) were similarly represented, but the groups with 10-20 years (29%) and more than 20 years of professional experience (29%), respectively, made up the majority of the sample. Overall, a majority of 237 teachers (67%) reported having visited an OSLE in the past two years. Among these teachers, 141 (59%) actually visited more than one OSLE with their students during this time. The learning sites visited were mainly in the categories of "museums/exhibitions/science centers" (36%) and "student laboratories" (34%), while "industrial companies/ research groups" were mentioned much less frequently (14%). Among the other places mentioned (16%) were, e.g., forests/ponds (6 mentions), universities (4 mentions), zoos and planetariums (each 3 mentions). All other places were mentioned less than three times.

Figure 1. Types of OSLE visited by teachers (237 teachers, 378 visits)



Results

Correlation between personal data, school type, and out-of-school learning site attendance

First, the descriptive data of the teachers (work experience in years, year of birth, gender, attendance of an in-service training on media use in the last two years) in combination with the data regarding the attendance of an OSLE (yes/no), and the type of learning location attended were examined. In the majority of cases, no relations were found between the respective variables, so it can be assumed that the attendance of OSLE and their type is independent of these personal variables. One exception is the relation between attending a training course on media use in the last two years and attending an extracurricular learning venue. The percentage of teachers who used OSLE was significantly higher among those who had attended such training (73% vs. 59% for teachers who had not).

The next step was to examine whether there are relations between the educational track of the school (e.g., grammar school, community school without upper-level track, etc.) or the school level taught (lower secondary level/upper secondary level) on the one hand, and the attendance and type of OSLE on the other hand. Again, the data and test statistics show no evidence of dependence between the variables, so it can be assumed that attendance at OSLE and the type of OSLE do not depend on the type of school or the level taught.

Relation between school subjects and out-of-school learning site visits

The survey also collected data on the subjects taught by teachers. Note that in the German context, secondary-level teachers are typically educated as subject specialists for two subjects. Mathematics (60% of teachers) proved to be by far the most frequently represented subject. Physics (37%), chemistry (30%), and biology (30%) teachers were also found in considerable proportions in the sample. Computer science (18%) and natural sciences (15%) were other frequently reported subjects among the participants.

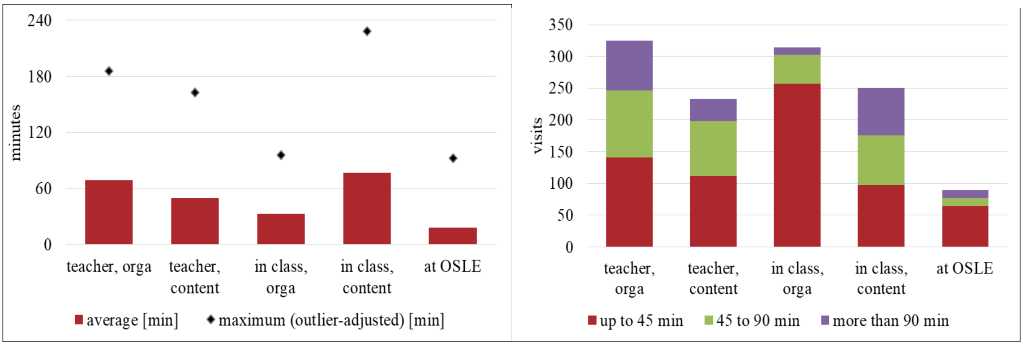
It investigated whether dependencies exist between the subjects taught by a teacher and the attendance and type of OSLE. Several significant relations were found. On the one hand, teachers of certain subjects (biology, science, after-school classes) show a significantly higher proportion of OSLE visits (78%/ 82%/ 83% vs. average 67%), while among math teachers, a significantly lower proportion (61%) used OSLE.

Second, the findings give reason to believe that there is a relationship between a teacher's subjects and the type of learning site visited. While biology teachers are more likely to visit student labs (39% of learners vs. 34% on average), math and science teachers are more likely to use museums and science centers as OSLE (45% vs. 36%). Computer science teachers, on the other hand, are more likely to conduct visits to industrial companies or research groups (27% vs. 14%). Further, the number of subjects taught was positively in a significant way related to the probability that this teacher visits OSLE.

Time spent on preparatory and follow-up work with students

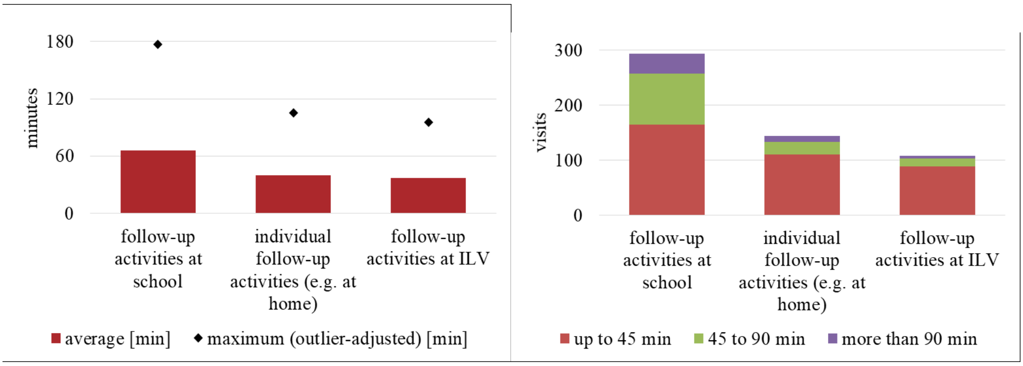
The time spent on preparation and follow-up varies widely across the sample. In the study, four different types of preparation were queried: organizational and content preparation done by the teacher in advance (i.e., identifying the right place, planning the trip), as well as organizational and content preparation in class with students (i.e., communicating the trip schedule, repetition of specific expertise). On average, organizational preparation took 33 minutes, while content preparation in class took 71 minutes. Two-thirds of the visits had at least 45 minutes of preparation in class; thus, they could be assumed to be reasonably well prepared. The times for the different learning locations differed significantly.

Figure 2. Average preparation time per visit. Shares of teachers that spend 1 lesson (45 min), 2 lessons (90 min), or more on preparation (237 teachers, 378 visits).



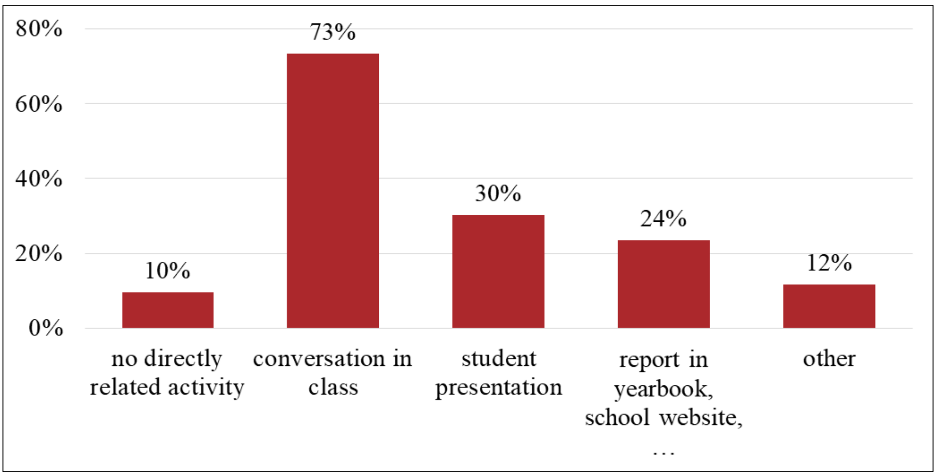
About 90% of teachers conducted follow-up work with students after the visit. On average, 59 minutes were spent on follow-up work in class, as well as 20 minutes for individual student follow-up (e.g., at home).

Figure 3. Average time for follow-up work in class, at home or at the OSLE. Shares of teachers that spend 1 lesson (45 min), 2 lessons (90 min) or more on follow-up activities (237 teachers, 378 visits)



Teachers visiting OSLE used quite different activities for the follow-up work: Most often, a class discussion was conducted, followed by student presentations and some kind of report, e.g., in a yearbook or on the school website. Other, less often mentioned activities include coursework, protocols, project work, worksheets, calculations, creating models, follow-up tasks of the zoo, and evaluation of measurement results.

Figure 4. Formats of follow-up activities performed at school / at home after the OSLE visit (237 teachers, 378 visits)



Discussion and Conclusions

The analysis shows that teachers' personal characteristics, such as professional experience, age, and gender, have no influence on the frequency of visiting OSLE. The only significant variable related to visiting was participation in in-service professional development on media use in the past two years. While the data do not allow us to draw conclusions about causality, one possible explanation would be that teachers interested in teaching innovations tend to both participate in in-service training and use OSLE. On the other hand, the influence of the school environment is also conceivable: Schools where in-service training is considered important and encouraged may also create school climates that are more open to OSLE visits. The type of school and the school level were found to be not related to the frequency of visits or to the type of OSLE in our sample. In contrast, regarding the subjects taught by the teachers, there are clear relationships, both to the frequency of learning site visits and the choice of sites. Biology and general science teachers, as well as teachers running after-school programs, have a considerably higher probability of visiting OSLE than other teachers. Math teachers use fewer OSLE. Also, regarding which sites are chosen, the teachers in the subjects differ: Biology teachers prefer student labs, whereas science and math teachers favor museums and science centers. Computer science teachers are predominantly found visiting industrial companies or research groups. An interesting finding is that the number of subjects taught is positively linked to the visit of OSLE. One possible explanation could be that engaged teachers tend both to teach more subjects and to take advantage of offerings such as extracurricular venues. This fits well with the above findings that teachers who have attended further training measures on media use also visit OSLE more frequently. Thus, overall, it appears that while the respective subject influences the choice of venue, the main factor for visiting tends to be committed teachers and/or a positive school environment.

Limitations

The sample was obtained through mailings and surveys at teacher conferences. Therefore, a positive selection of teachers is to be expected – usually, especially engaged teachers attend conferences or answer surveys about extracurricular learning venues and media use. Therefore, the frequency of attendance is probably overestimated. For the analyses within the subsample of teachers that visit OSLE, this does not change the relevance of the data since non-visiting teachers cannot contribute here. The analysis used data from several states that vary in size and have different school systems or opportunities for out-of-school learning. While the data somewhat reflect the diversity in the education system in Germany, it is not fully representative of Germany. The data was collected before the pandemic. However, most OSLE are now back to normal operation again.

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Spoiler Alert! Portrayal of the Climate Crisis and Human Response in Blockbuster Movies: A Thematic Analysis

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Climate change is commonly used as a background or a prominent topic in science fiction and disaster blockbusters. It is typically portrayed in these films as a catastrophic event triggered by human activity with devastating consequences. Since movies play an important role in informal science education, these blockbusters can not only raise awareness but also lead to uncertainty or skepticism regarding climate change. In this study, we take a critical look at how climate change is portrayed in films by conducting a thematic analysis of ten blockbusters in terms of the effects of climate change depicted, the human response to it, the timeline of climate-related events depicted, and the emotions evoked. From our analysis, the climate change implications these movies depict include resource shortages, extreme weather occurrences, starting a new Ice Age, rising sea levels, and extra-terrestrial threats. As per human response, in the majority of the movies, the problem is resolved with an "easy fix" or results in society's collapse. Finally, in most of the movies, the climate-related events unfold in a matter of days, while the dominant feeling is fear. The upshot of these findings is that they emphasize the need for a) making blockbuster climate change portrayals more accurate, b) discovering educational strategies to make audiences more critical viewers.

Keywords: Climate change communication, informal education, blockbuster movies

Theoretical Framework

Movies as a means of Informal Science Education

Science education extends beyond the academic system. Informal Science Education (ISE), which happens outside the classroom is crucial for students, as well as the public, in terms of understanding scientific concepts and increasing interest in science (Lin & Schunn, 2016). Movies serve as a significant informal education factor and are thus regarded as an effective medium for scientific communication under certain conditions (Kizilcik et al., 2014), as they stimulate observation, experimentation skills, imagination, curiosity, and reasoning capacity (Arroio, 2007). Movies have been used in various educational settings, with very promising results. Barak & Dori (2011) used web-based animations, that significantly enhanced the scientific curiosity, the acquisition of scientific language, and the development of scientific thinking in primary school students. Both Arroio & Farías (2011) and Ayvacı & Özbek, (2019) used movies and documentary films as a tool for science teacher training, with promising results which indicates the potential of movies as a powerful educational tool.

Climate Change Seen Through the Cinema Lens

As the world becomes more immersed in the landscape of anthropogenic climate change, an increasing number of researchers are investigating the most effective ways to communicate this multifaceted and global issue. They identify the following challenges to consider when communicating climate change to the public, among others:

(a) Engagement of the public, rather than simply having information, is critical (Lorenzoni et al., 2007). Numerous studies assert that the "knowledge deficit model," which holds that all that is required to change public perception is to fill the public's gaps in scientific knowledge with information, is insufficient (Simis et al., 2016). Hobbs-Morgan (2017) contends that films are an effective means of instilling in the public the structural and slow violence of climate change and that portraying it as a distant "scientific" or "technological" problem can lead to non-engagement.

(b) Hopeful and fearful climate change representations in movies differ in terms of audience engagement and policy support. Fearful portrayal may raise the level of concern in the audience, but only temporarily (Sakellari, 2015). Fear, while effective in attracting attention, often fails to foster sustained engagement or support for climate policies according to Stern (2012), who also observed that fear is particularly ineffective with climate change deniers. Conversely O'Neill & Nicholson-Cole (2009) found that nonthreatening representations (namely hope and positive imagery) linking to everyday emotions and concerns are more effective in engaging audiences. Moreover, (Nabi et al., 2018)this study investigates the role of emotion, fear and hope specifically, in the gain/ loss framing of environmental policy initiatives. The 2 (threat vs. no threat emphasized the role of hope in enhancing the impact of gain-framed messages on climate policy attitudes and advocacy.

(c) The counter-intuitive time scales associated with climate change pose a challenge to its effective communication. Pahl et al. (2014) propose techniques for "bringing the future closer, and making it more personal," and movies are an effective way of bridging abstract time scales with human experience. Movies, on the other hand, can cause misunderstandings if scientific accuracy is "sacrificed" for the sake of entertainment. For example, a survey of cinemagoers in England who saw "The Day After Tomorrow" conducted by Balmford et al. (2004) found that the level of concern increased while the level of public understanding decreased after viewing a film depicting climate change with no scientific accuracy.

Research Questions

Based on the foregoing, we examined ten blockbuster movies that depict climate change as either the main theme or a backdrop issue. We will attempt to answer the following research questions about how climate change is portrayed in the identified movies:

- RQ1: Which aspects of climate change are portrayed in blockbuster movies?
- RQ2: What themes emerge regarding the human response to the issue, and what is the timeframe in which climate-related events occur?
- RQ3: Do blockbuster movies about climate change predominantly convey fear or hope in their narratives and visual representations?

Methodology

Our study employs thematic analysis to examine how climate change is portrayed in blockbuster movies. Our criteria for the movies we included were:

(a) The direct or indirect depiction of climate change.

(b) The movie is not about disasters, such as volcanoes or earthquakes.

(c) Non-documentary films.

(d) Blockbuster with global distribution.

The initial search of the IMDb database using the keyword "climate change," yielded 1,041 movie titles. The result was then refined by selecting the category Feature Film, which yielded 266 titles. Finally, within the criteria we mentioned above, we identified ten films through manual screening. Notably, "Don't Look Up" was included as it metaphorically represents climate change through the allegory of a comet hurtling towards Earth, as stated by its director, Adam McKay.

A coding scheme was developed to conduct the thematic analysis (see Table 1). Each of the ten selected movies was watched and analyzed for the presence of these themes by two coders to ensure a comprehensive and unbiased analysis. The coders independently watched each film and then collaboratively discussed and recorded their observations. Data were systematically organized using a spreadsheet to facilitate analysis and compare the coders' insights. The following section details the analysis and interpretation of the results.

Table 1. Coding scheme for thematic analysis.

Theme	Codes	Explanation
Impact of climate change	Flooded Earth	The polar caps have melted, rising the sea level.
	Resources shortage	Earth is a wasteland with minimum resources, unable to sustain life as we know it.
	New Ice Age	The planet is covered by permafrost.
	Extreme weather events	
	Extra-terrestrial threat	
Type of movie	Allegory	
	Dystopia	
	Disaster	
Time frame of climate change events	Days	
	Decades	
Human Response	Easy fix	Humanity "solves" the climate crisis in a swift action.
	Change for the better	Humanity recognizes its mistakes and tries to do better.
	Collapse	The planet's ecosystem collapses and with it, the human society.
Fear or Hope inducing	Fear	The overall tone of the film despite moments of hope.
	Hope	The overall tone of the film is one of the possibilities of a better future despite moments of fear and danger.
	Hope & Fear	Balance between the elements that evoke hope.

We analyzed ten selected movies, listed chronologically by their release date: "Waterworld," "The Day After Tomorrow," "The Day the Earth Stood Still," "Avatar," "Snowpiercer," "Pacific Rim," "Interstellar," "Mad Max: Fury Road," "Geostorm," and "Don't Look Up." The genre analysis revealed that nine are categorized as science fiction action films, while one is a black comedy.

RQ1: Climate change is portrayed as catastrophic, widespread, and anthropogenic in all of the movies examined. The main themes are:

(a) Scarcity of resources (water, fuel, food). In these movies, the planet is not able to sustain life as we know it, and society collapses as a result.

(b) Extreme weather events, such as droughts, hurricanes, ice storms, and dust storms, that destroy entire cities.

(c) Earth enters a new Ice Age. In the Day After Tomorrow, this is due to the effects of climate change on the Gulf Stream, whereas in Snowpiercer, it is due to an attempt to mitigate global warming by releasing aerosols into the atmosphere, that backfires in a global freeze.

(d) Flooded Earth. In Waterworld, the world is submerged due to a 7.600 m (!) rise in sea level. Although these depictions have a scientific basis, another intriguing portrayal emerges:

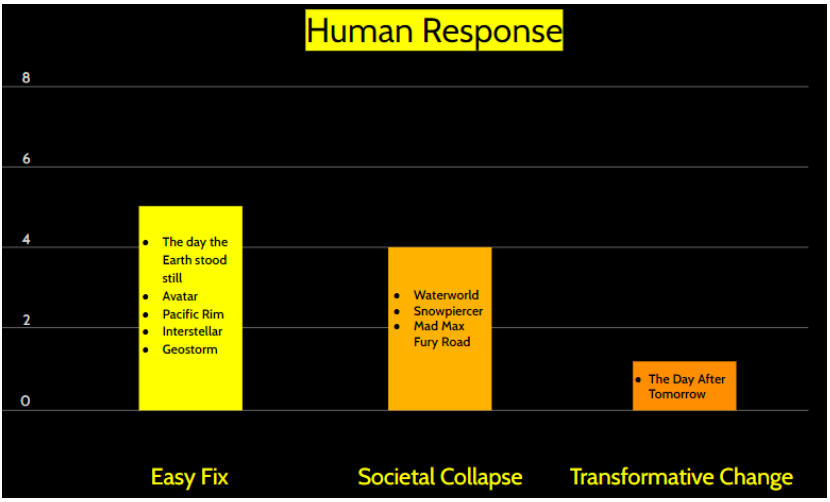
(e) Extraterrestrial threat. It includes a "good alien" who comes to save Earth by wiping out "bad humanity" (The Day the Earth Stood Still), alien monsters trying to colonize Earth because humans created the ideal conditions with climate change (Pacific Rim), and an approaching comet as a climate change allegory (Don't look up).

Table 2. Identified movie themes.

Impact	Flooded Earth	Waterworld
	Resources shortage	Waterworld, Avatar, Interstellar, Snowpiercer, Mad Max Fury Road
	New Ice Age	The Day After Tomorrow, Snowpiercer
	Extreme weather events	The Day After Tomorrow, Interstellar, Geostorm
	Extra-terrestrial threat	The Day the Earth stood still, Pacific Rim, Don't look up

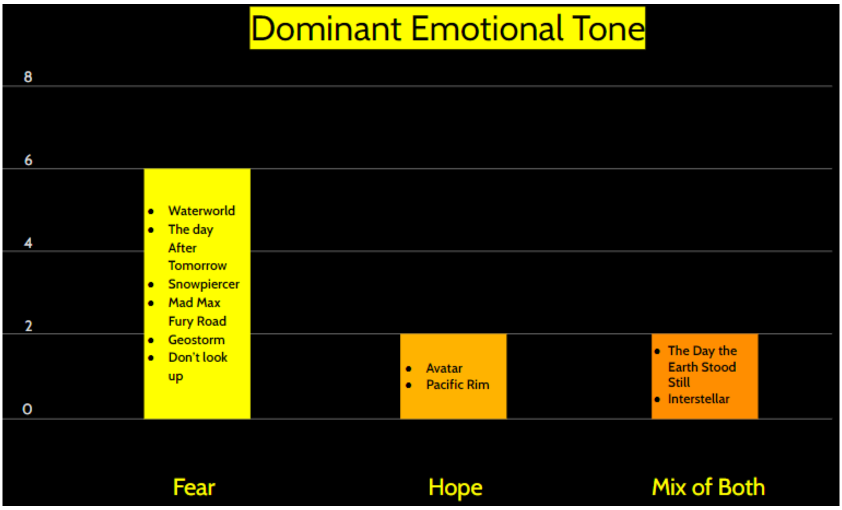
RQ2: The analysis identified three categories of human response to climate change within the movies: "Easy Fix", "Societal Collapse", and "Transformative Change". Half of the movies conclude with an "easy fix", while in four the result is societal collapse. Remarkably, only "The Day After Tomorrow" offers a narrative of "Transformative Change", suggesting a rare but positive shift in human behavior in response to climate change. In addition, most of the movies examined (six out of ten) depict climate change events unfolding in a matter of days, while four movies depict events unfolding over decades. Easy fixes and short timeframes can lead to the misconception that humanity can wait and not tackle climate change until we reach a "tipping point".

Figure 1. Categories of human response



RQ3: Regarding the emotional tone, the predominant emotion elicited by these movies is fear, with seven films, including "Waterworld", "The Day After Tomorrow", "Snowpiercer", "Mad Max: Fury Road", "Geostorm", and "Don't Look Up", utilizing this tone. In contrast, "Avatar" and "Pacific Rim" predominantly evoke a sense of hope. Notably, "The Day the Earth Stood Still" and "Interstellar" present a mix of both fear and hope, highlighting a nuanced approach to emotional engagement with climate change themes.

Figure 2. Categories of dominant emotional tone



Discussion

The study's thematic analysis of climate change in blockbuster movies highlights its dual role in Informal Science Education, raising awareness while also shaping public perceptions. Using fear in these narratives, as shown by our findings, may grab audiences' attention but also risks a sense of helplessness, particularly when paired with "Easy Fix" or "Societal Collapse" scenarios. This points to a need for more "Transformative Change" stories that can empower audiences to act on climate issues.

The potential for movies to reinforce misconceptions and biases suggests that critical viewing is essential, so enhancing the accuracy of climate portrayals in blockbusters and developing educational initiatives that promote media literacy is of great importance. This approach can help audiences navigate the line between entertainment and education, fostering a more scientifically informed public ready to engage with climate challenges.

Cinema's potential in influencing public understanding of science is undeniable, but it must be wielded with a responsibility to encourage informed and constructive engagement with climate change.

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What typeS of Experimental Activites ARE Appreciated by Students INclined Towards Studying sTEM?

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Our department offers several experimental activities for upper-secondary school students. These activities vary in their respective characteristics, which may appeal differently to various groups of students. This contribution focuses on three specific activities – pure lecture demonstrations, popularizing science show and practical lab work. A questionnaire based on Intrinsic Motivation Inventory was administered to students attending these activities. The relationship between different aspects of intrinsic motivation triggered by these activities and students' intention to study STEM at university level was analysed using two-way ANOVA and linear regression. The results show that any experimental activity is perceived more positively by students prone to studying STEM. The capacity of practical work and lecture demonstrations to trigger situational interest drops more rapidly with the decrease in intention to study STEM than this capacity of science shows. Popularizing science shows trigger highest interest in all students, yet for students prone towards studying STEM it is comparable to interest triggered by practical lab work.

Keywords: Situational interest, experimental activities in physics, STEM education

Introduction

Experimentation is one of the key aspects of teaching physics. Many teachers not only conduct experiments in their classrooms, but also take the opportunity to participate with their students in experimental activities offered by external educational organisations. Our Department of Physics Education offers plenty of such activities to upper-secondary school students. We have turned our research focus towards three of these activities with quite different characteristics:

Physics demonstrations for upper secondary school students (DEMOs)

A 75 minute thoughtfully chosen string of intriguing demonstration experiments (Kácovský & Snětinová, 2021). This is an out-of-school activity, frontally performed by lecturers from our department. These experiments involve only a handful of volunteers from the audience.

The emphasis is put onto theoretical explanations of the demonstrated physics phenomena.

Physics in all senses (PAS)

Science show consisting of frontally performed experiments in the students' home schools by two well-trained pre-service physics teachers from our department (Kácovský & Koudelková, 2016). These experiments involve many volunteers; students are generally more included into the show. The emphasis is put onto presentation of intriguing experiments appealing to human senses and their conceptual understanding.

Interactive physics laboratory (IPL)

Practical lab work taking place in specifically designed environment at our university (Kácovský et al., 2023), during which students work independently in small groups. At least two lecturers are present in the lab to guide the students. The emphasis is put onto independent hands-on experimenting, linking theory to experimental set-up, making predictions, conducting both quantitative and qualitative experiments, evaluating and interpreting data, etc.

The activities vary in numerous aspects – ranging from pure lecture demonstrations to practical work, equipment that is used, cognitive complexity of physics topics, etc. The appeal of these activities to different students may vary due to such aspects. In general, experimental activities, both demonstration experiments and practical work, are considered to be capable of generating student interest (Abrahams, 2009; Erickson et al., 2020; Kácovský & Snětinová, 2021; Kácovský et al., 2023; Lin et al., 2013; Palmer, 2009; Röllke & Großmann, 2022; Walton, 2002), albeit situational rather than individual. But which activities are more and less effective in this respect for different groups of students?

There are studies suggesting that the fact that physics is oftentimes perceived as difficult is a barrier that students must overcome in order to choose this subject for their future career (DeWitt et al., 2019). Hence, we would like to know how do the three specific activities mentioned above appeal to students with different perspectives on studying STEM at university, thus we have formulated the following research question:

Does the intention to study STEM at university influence aspects of intrinsic motivation triggered by different types of activities?

Theory

In this study, we emphasize the students' intrinsic motivation in the context of physics experimentation. We draw on the framework of self-determination theory (SDT; Deci and Ryan (1985)).

The intrinsic motivation to act in a particular situation is closely linked to interest, regarded as its antecedent or precondition (Hidi & Harackiewicz, 2000; Schiefele, 2009). The conceptual closeness between interest and intrinsic motivation is a key aspect of psychological measurements in SDT. For instance, within the multidimensional Intrinsic Motivation Inventory (IMI, Center of Self-Determination Theory, n.d.), participants' expressed interest/enjoyment serves as an indicator of intrinsic motivation.

The process of interest development has two primary stages – situational and individual interest. Situational interest, being short-term, is characterized by an immediate affective response to a given content or activity (Renninger & Hidi, 2016), whereas individual interest is a relatively stable, enduring orientation toward specific subject areas (Schiefele, 2009).

Triggering situational interest marks a crucial initial stage in the interest development process. Activities designed to trigger interest are expected to be challenging, novel, surprising, and complex (Harackiewicz et al., 2016), aligning seamlessly with the character of our undertaken activities.

Methodology

This study followed a quantitative approach applying a Likert-scale questionnaire. The respondents are upper-secondary school students (15–20 years) who participated in the three activities in the years from 2017 to 2020. Three versions of the questionnaires (for DEMOs, PAS, IPL) were used, with slight variations in wording of items where necessary (Department of Physics Education, 2024). The questionnaires consisted of three parts:

A. Basic information about respondents – type of school, gender, age, year of study (1^{st}–4^{th}), grade in physics and intention to study physics and STEM at university level (rated on 5-point Likert scale).

B. Students' perception of physics as a school subject, self-reported giftedness and diligence in physics rated on 5-point Likert scales.

C. Students' perception of the just experienced activity – formulation of these 7-point Likert scales is based on various aspects influencing intrinsic motivation using Intrinsic motivation inventory (IMI; Center of Self-Determination Theory, n.d.) within the frameworks of self-determination theory (Ryan & Deci, 2020). Included aspects are *effort/importance*, *value/usefulness*, *pressure/tension* and *interest/enjoyment*, each represented by at least four items.

The questionnaires were fully anonymously administered (in paper form) to the students immediately after the end of each instance of these activities. Respondents were informed that by completing and returning the paper questionnaire, they consented to data processing. Two-way ANOVAs were performed in IBM SPSS Statistics 26, and linear models were estimated using jamovi on the digitized data.

Data processing

The data were filtered using pairs of direct- and reverse-worded items. Table 1 shows basic information about all the respondents organised by the activity in which they participated (DEMOs, PAS, IPL).

Table 1. Basic information about the respondents.

Activity	N	Gender [%]	Year of study [%]	Intention to study STEM [%]				
		female/ male	1st / 2nd / 3rd / 4th	definitely **no**	rather **no**	don't know	rather **yes**	definitely **yes**
DEMOs	4808	53 / 45	32 / 33 / 28 / 7	21	20	15	23	21
PAS	2840	55 / 43	32 / 37 / 29 / 1	24	21	15	21	20
IPL	1999	37 / 60	25 / 38 / 28 / 9	10	18	15	26	31

Principal axis factoring (overall KMO .92; Bartlett's test of sphericity $p < .001$) with oblimin rotation showed four-factor structure (in accordance with IMI dimensions), with one factor (*pressure/tension*) being virtually uncorrelated with the other three factors (Pearson's r's < .14). Reliability analysis (using Cronbach's α) showed that the *pressure/tension* dimension behaves poorly[1] and this dimension was omitted from further analyses. Resulting Cronbach's α is .91 for the whole questionnaire; .86 for the *value/usefulness* dimension; .76 for the *effort/importance* dimension and .87 for the *interest/enjoyment* dimension.

Linear models are estimated by scoring the intention to study STEM from −2 for definitely no, up to 2 for definitely yes. Using this symmetrical scoring improves accuracy of estimates of the intercept parameter as well as its indicative value as a measure of central tendency for the data.

Results

As can be seen from the group means in Table 2, an average in the three considered IMI dimensions tends to increase with increasing *intention to study STEM* regardless of the activity. A two-way ANOVAs were performed to analyse the effect of activity and *intention to study STEM* on the used IMI dimensions.

Table 2. IMI dimension means with S.E. (in brackets) grouped by activity and *intention to study STEM*.

	interest/enjoyment			*value/usefulness*			*effort/importance*		
intention to study STEM	DEMOs	PAS	IPL	DEMOs	PAS	IPL	DEMOs	PAS	IPL
definitely no	4.92 (.04)	5.48 (.05)	5.04 (.08)	5.10 (.03)	5.05 (.04)	5.20 (.07)	3.59 (.04)	4.10 (.05)	4.48 (.09)
rather no	5.42 (.04)	5.79 (.05)	5.42 (.06)	5.59 (.03)	5.50 (.04)	5.51 (.06)	3.91 (.04)	4.41 (.05)	4.58 (.07)
don't know	5.45 (.04)	5.75 (.06)	5.55 (.07)	5.55 (.04)	5.37 (.05)	5.60 (.06)	4.03 (.05)	4.37 (.06)	4.74 (.07)
rather yes	5.60 (.04)	5.90 (.05)	5.78 (.05)	5.68 (.03)	5.54 (.04)	5.84 (.05)	4.10 (.04)	4.39 (.05)	4.88 (.06)
definitely yes	5.73 (.04)	6.02 (.05)	5.96 (.05)	5.79 (.03)	5.68 (.05)	5.86 (.04)	4.15 (.04)	4.52 (.05)	4.94 (.05)

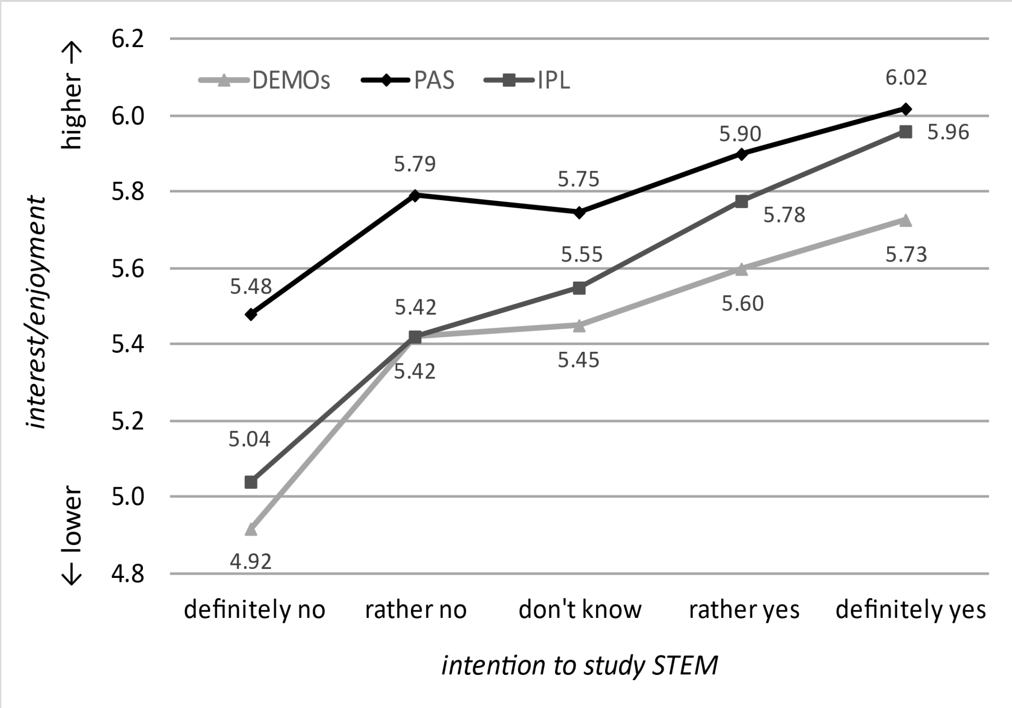
Results of the two-way ANOVAs stated in Table 3 reveal a statistically significant interaction (at .01 level) between type of activity and *intention to study STEM* for *interest/enjoyment*. Interaction effect is insignificant for the remaining two dimensions, suggesting that the *intention to study STEM* polarises students attending the three activities differently only in *interest/enjoyment*. Analysis of main effects shows that both type of activity and *intention to study STEM* have a statistically significant effect on all used IMI dimensions.

Table 3. Two-way ANOVA analyzing effects of activity and *intention to study STEM*.

IMI dimension	Source of variation				R^2_{adj}
interest/enjoyment	*activity*	2	81.39	<.001	.060
	STEM	4	86.24	<.001	
	interaction	8	3.07	.002	
value/usefulness	*activity*	2	43.91	<.001	.055
	STEM	4	74.90	<.001	
	interaction	8	1.27	.254	
effort/importance	*activity*	2	253.18	<.001	.078
	STEM	4	30.71	<.001	
	interaction	8	1.66	.102	
	within	9602			

Since *interest/enjoyment* is the only IMI dimension with significant interaction effect, Figure 1 shows the means of *interest/enjoyment* triggered by different types of activity with respect to the *intention to study STEM*. DEMOs trigger interest the least and PAS the most (out of these three activities) without regard to the *intention to study STEM*. The level of interest triggered by all types of activity increases with increasing *intention to study STEM*, however, the interest triggered by IPL appears to be increasing at highest rate.

Figure 1. Interest/enjoyment triggered by different activities.



Since the relationship between *intention to study STEM* and IMI dimensions is increasing, all slope coefficients *a* stated in Table 4 are positive. The only dimension with at least one slope significantly different from the others is *interest/enjoyment*, which corresponds to the results of the two-way ANOVA. *Interest/enjoyment* triggered by DEMOs and IPL increases at comparable rate, while PAS polarizes the students significantly less.

Table 4.Parameters of linear regression of *intention to study STEM* on IMI dimensions.

Activity	*interest/enjoyment*			*value/usefulness*			*effort/importance*		
	a (S.E.)	*b (S.E.)*	R^2	*a (S.E.)*	*b (S.E.)*	R^2	*a (S.E.)*	*b (S.E.)*	R^2
DEMOs	.18 (.01)	5.42 (.02)	.042	.15 (.01)	5.51 (.02)	.038	.13 (.01)	3.95 (.02)	.020
PAS	.12 (.01)	5.79 (.02)	.024	.13 (.02)	5.32 (.02)	.026	.09 (.02)	4.35 (.02)	.010
IPL	.21 (.02)	5.56 (.03)	.063	.15 (.02)	5.64 (.02)	.036	.12 (.02)	4.73 (.03)	.018

As to the interpretation of intercept *b*, the highest *interest/enjoyment* is triggered by PAS, followed by IPL and DEMOs respectively. Despite that, the perceived *value/usefulness* of PAS is the lowest out of the three activities. Hands-on experimenting in IPL is considered to be the most valuable out of the three activities. As for the *effort/importance*, it corresponds to the required intensity of student engagement on the activity – the highest effort is elicited by hands-on experimenting in IPL, medium effort is required during the PAS science show with large number of volunteers actively participating in the show, and the lowest *effort/importance* is perceived during the lecture demonstrations DEMOs, where students are mainly passive.

Discussion and Conclusion

With increasing intention to study STEM at university, a situational interest triggered by any type of activity increases as well, yet interest triggered by practical work in IPL and the frontally performed shows in DEMOs rises at faster pace than interest triggered by the science show PAS. In IPL there is more concentrated attention on individual students, which might feel uncomfortable for students that do not plan to study STEM, and vice versa students that do intend to study STEM might feel more appreciated in such situation.

The students not planning to study STEM may find the flashy, lively, intriguing, and conceptually easier experiments performed during PAS more appealing than the DEMOs experiments with higher cognitive load and more theoretical explanations. This can be the reason why the intention to study STEM polarises DEMOs audience more than it does audience in PAS.

PAS triggers interest the most with disregard to intention to study STEM. Although its lead is negligible for students inclined towards studying STEM, it is gaining dominance over DEMOs and IPL as the intent to study STEM decreases. During PAS, everyday equipment is used, many volunteers are incorporated, mostly conceptually simpler physics is being demonstrated in a rather popularising way. This may appeal a lot to those who do not intend to study STEM further, yet to those who do, although intriguing, they might perceive a missing 'added value' regarding their STEM education. Since an important goal of PAS is popularization of physics, more so than for the other two activities, our research shows that it fulfils its purpose.

Based on our data, practical work appears to be most suited for students who are inclined towards studying STEM. It triggers substantial amount of situational interest while being perceived as valuable and useful; these students are also willing to put extra effort into such activities.

Frontal experimentation has its undeniable merit – it has a potential to reach out to a large number of people simultaneously. When performed as a popularising show frontal experiments trigger more situational interest than traditional demonstrations in all students, yet this takes its toll – it is perceived as being less useful than hands-on experimenting or lecture demonstrations. Nonetheless, *raison d'etre* of performing science shows is obvious from our data – it triggers a lot of situational interest in student who are not prone to study STEM and thus it has a potential to improve their attitudes towards STEM in general.

Acknowledgement

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Out-of-classroom Science Education in Europe: a Mapping Study of Practices and Paths to Accreditation

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Research interest in science education outside the classroom (EOC) has received increased attention in the last few years in response to the need to provide education connected to contemporary socioscientific challenges. Formalising EOC practices involves discussing accreditation processes for initiatives that expand learning possibilities regarding curricular demands and resources. Accreditation procedures can ensure the quality of education as well as the safety of students. This paper presents the results of a mapping study aimed at contributing to the understanding of how EOC is structured in various countries in Europe to assess gaps and opportunities to further the discussion about introducing an EOC accreditation framework. Following a systematic mapping methodology, we analysed 65 papers and 187 initiatives, spaces and programs used for EOC activities. Regarding curriculum, we identified a predominance of biology content, student-centred pedagogical approaches implemented in multiple sessions, and EOC activities in parks and museums. We also identified a significant lack of information on (i) the degree of curriculum alignment of EOC programs with country-specific curriculum parameters, (ii) learning assessment processes, (iii) the professional qualifications of staff involved in EOC initiatives, and (iv) children's school needs in terms of accessibility, inclusion, and safety. Nevertheless, the variety of mapped practices can contribute to advancing discussions about good EOC practices and thinking about ways to accredit EOC. This study forms part of the EU-Horizon 2020-funded project OTTER (Outdoor Science Education for a Sustainable Future).

Keywords: Accreditation, Education outside the classroom, Inclusion

Introduction

In the majority of schools in Europe, formal education is still predominant, but integrating Education Outside the Classroom (EOC) is evolving as a possibility to achieve a more critical and comprehensive education (Eurydice, 2007). EOC is characterised by activities based on the school curriculum but performed in settings outside the classroom. The reported outcomes of EOC approaches have been many, including higher scientific reasoning abilities among students' interactive, cognitive, and logical thinking skills, practical mathematics, skills, and knowledge transfer to outside school improvements in self-esteem, motivation, and concentration, improvements of social skills, of physical motor skills and development of language and communication (McCormack et al., 2022).

Exploring learning opportunities outside of formal schooling opens up a world of educational possibilities from a curricular point of view and the places where these activities can be carried out. The potential of EOC and the diversity of approaches used to implement it create the need for recognition and accreditation. Those procedures can ensure students' quality of education and safety during EOC activities. However, without a clear understanding of the practices and spaces in Europe used for EOC, it is impossible to debate how we can accredit initiatives (e.g., educational programs, informal learning environments, materials, and organizations) for this purpose. In this context, this study (part of the EU-Horizon 2020- funded project OTTER Outdoor Science Education for a Sustainable Future) is intended to contribute to understanding how EOC is structured and how it occurs in practice in various European countries. Through this mapping study, we, therefore, pretend to identify places, actions and educational programs that foster EOC (e.g., science museums, science centres, and botanical gardens). In doing so, we provide possible paths to assess gaps and opportunities for introducing an EOC accreditation framework.

Methodology

We present a two-way mapping of EOC practices in Europe to get a more comprehensive view of the field: *Practices to places* (in which we are mapping different types of EOC practices that are currently taking place and detailing the contexts in which they occur) and *Places to practices* (in which we are mapping different national sites with potential for EOC practices, but yet underdeveloped or not formalised) (Azevedo et al., 2023).

As EOC is a process, we sought to capture evidence and categorise essential elements for understanding how this process takes place in practice. For the first part, we drew on the results from a previous systematic literature review (McCormack et al., 2022) to broaden the scope of the results and more comprehensively include information from European contexts. For the second part, we created a database using a systematic mapping methodology (James et al., 2016), which included the steps of establishing the review team, setting the scope, setting inclusion criteria, protocol development, searching for evidence, screening evidence, coding, production of a systematic map database, describing and visualising the findings, report production, and supporting information. Systematic mapping is instrumental when there are open questions that require consulting different sources of evidence to be understood, as happens in our case (Bevan & Semper, 2016). The mapping was performed on educational and governmental databases and online pages. Data were analysed based on the definition of EOC and considering concerns in the literature about educational accreditation, e.g., safety, accessibility/inclusion and connection to the curriculum.

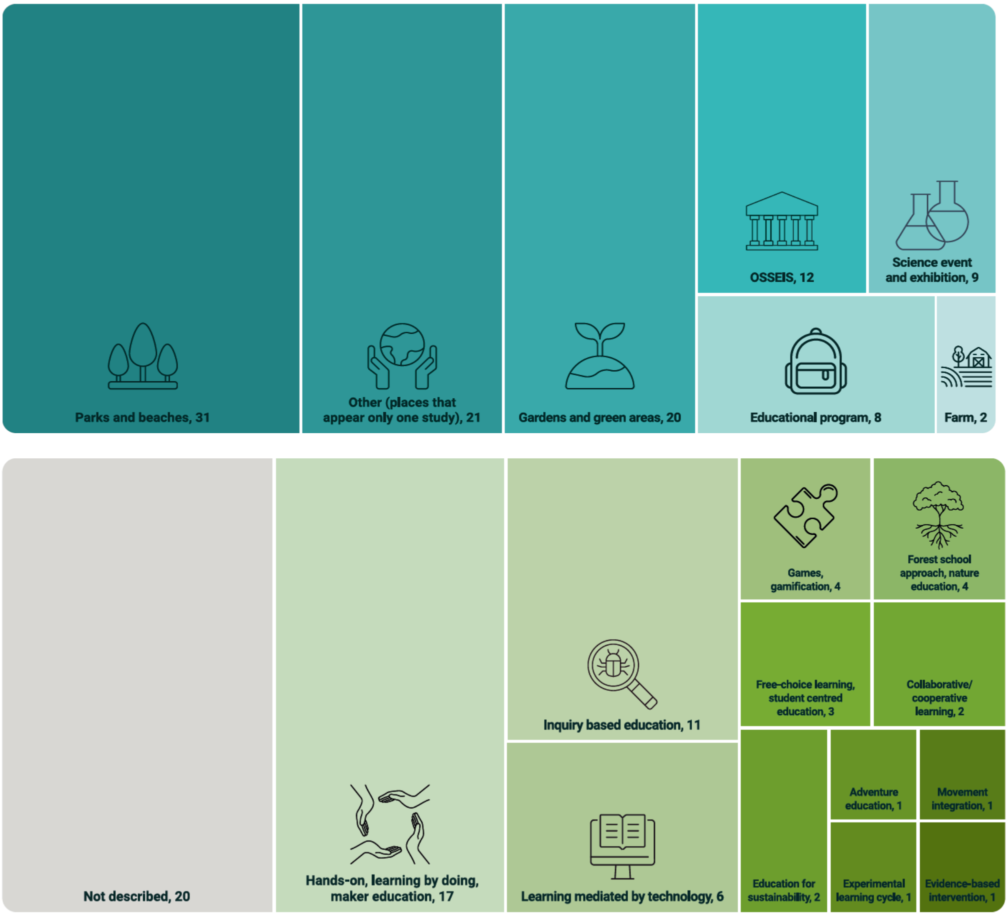
Findings

Practices to places

Considering the 65 studies included in this mapping stage, we identified studies from 14 European countries, predominately Finland and Ireland. There exists a great diversity of spaces and places used for EOC: 27 different types were mapped, and some of these categories included a significant internal variety (e.g., Out-of-school science education institutions/OSSEIS, including museums, science centres, zoos and aquariums). Studies on practices conducted in outdoor spaces such as parks and beaches (31), gardens and green areas (20), and farms (2) prevailed, representing more than half of EOC locations. Spaces promoted by institutions also featured in the findings of this study, specifically those that popularised scientific knowledge, either permanently, as in the OSSEIS, temporarily, as in science events and exhibitions, or in the form of educational programs (8). Finally, it is worth noting that several studies contemplated more than one space, place, or format used simultaneously (Figure 1).

Several studies presented more than one didactic approach. Moreover, it is important to note that almost 30% of the studies did not explicitly employ a didactic approach. Almost ⅓ of the occurrences belong to a single category (such as “Hands-on”, “Learning by doing”, and “Maker education”). Another third of the studies were distributed between the practices of “Inquiry-based education” (11) and “Learning mediated by technology” (6). The rest of the studies were categorised within a diverse range of approaches, among which the categories of “gamification” and “nature education” were notable (Figure 1).

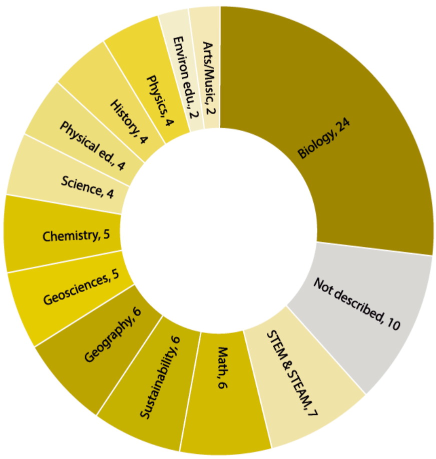
Figure 1. Studies according to spaces, initiatives, and places used for EOC (on top) and studies according to pedagogic approaches used for EOC activities (on bottom)



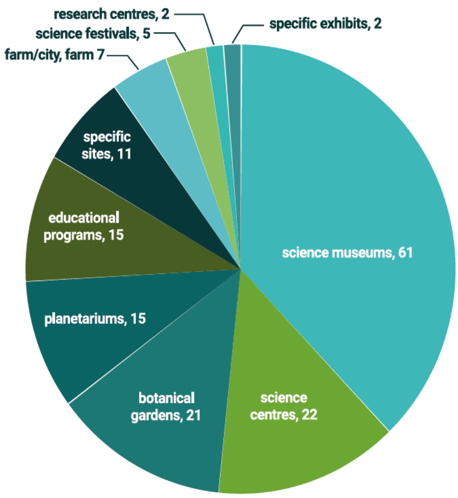
Short-duration activities (ranging from 2 sessions or 2 days to 5 days or 6 sessions) accounted for almost 25% of the total studies mapped. That leaves just over 20% with longer duration practices, ranging from one to four weeks to 2 to 9 months (9). Among the EOC activities described, 75% are composed of multiple sessions. The number of subjects and curriculum content covered during EOC activities is quite comprehensive, although there is a significant concentration in Biology, representing almost 30% of the total. One-third of the identified curricular subjects are represented by STEM/STEAM (7), mathematics, sustainability, and geography (6 each). The final third includes chemistry and geosciences (5 each); physics, history, science, and physical education (4 each); and environmental education and the arts, with only two observations each (Figure 2).

The 187 items from our database demonstrate the diversity of existing EOC places, events, and programs (countries included: Cyprus, Finland, France, Hungary, Ireland Spain, The Netherlands). However, despite the heterogeneity of this database, more than 30% are science museums, and about 12% are science centres. Adding the botanical gardens (21), educational programs (15) and planetariums (15), the mark of 70% of the total is exceeded. Another 15% are distributed among specific sites (11), farms (7), media science (4) and specific exhibits (2) (Figure 2).

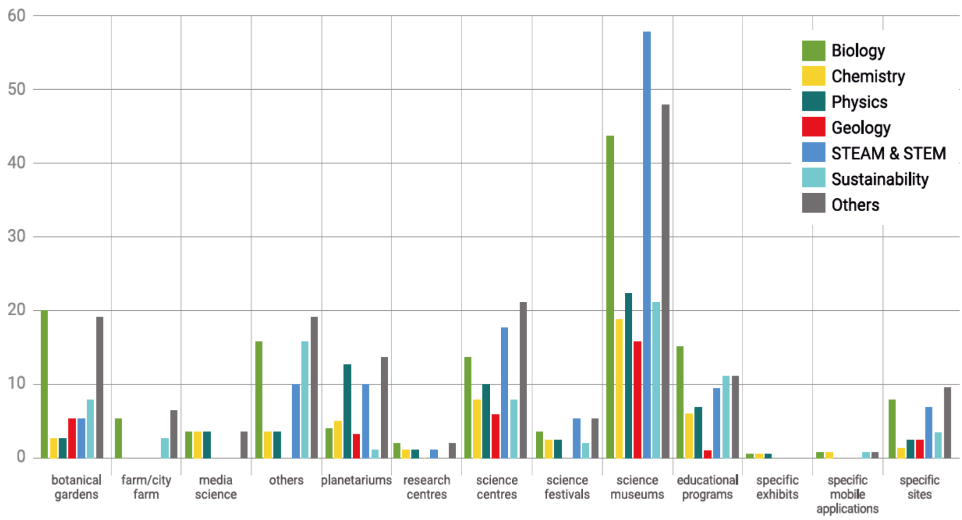
Figure 2. Studies according to curricular content covered during EOC activities (left) and places, events and programs for EOC practices (right). At the bottom, EOC contents according to places, events and programs for EOC activities.



Studies according to curricular content covered during EOC activities



Places, events and programs for EOC practices in the OTTER partner countries



Given our interest in the accreditation of EOC, we also examined issues related to safety, inclusion, and accessibility. We identified existing mechanisms to guarantee the complete use of these spaces by people in the most diverse conditions. However, in most cases, the related information is not accessible. It was observed that, among the places whose accessibility features are described, “science museums” have the most suitable structures for different audiences. The planetariums also stand out concerning accessibility. The exception is for the existence of “Structure for hearing and/or visually impaired children”, a criterion in which they score below average - probably due to the type of experience they have historically specialised in providing.

Discussion

What the findings of this mapping study suggest is that typically EOC is found mainly in northern European education contexts (e.g., Finland and Ireland) and involves outdoor activities (parks, beaches, green and open areas near the school environment), with hands-on activities, lasting from 1 to 6 sessions, on Biology, and adopting pre- and post-learning strategies. This may indicate that there is room for more diversity on all these fronts. On the other hand, it may also indicate that by publishing more on the subject, these countries may be doing more research, potentially helping to broaden the debate on effective ways to implement EOC.

By presenting the predominance of biology curriculum contents in the two levels of our mapping, it was possible to identify the tendency to work on curricular themes associated with these disciplines in different EOC formats. Likewise, STEAM/STEM, Sustainability, Physics, and Chemistry appear well-positioned in both parts of our mapping. This also illustrates an interdisciplinary trend since the curricular content observed significantly exceeds the total initiatives analysed. We observed that science museums are the most complete regarding curricular demands. This is likely due to the more generalist characteristic of these institutions, which cover many subjects. Not infrequently, they have multiple environments, each of them devoted with more emphasis to one of the areas listed above. The heterogeneity of subjects covered by these spaces is difficult to reproduce in other contexts, which are generally more limited or have more specific thematic focuses. This data also indicates the relevance of these institutions for EOC learning since we had specialists validating the items mapped, recognising the importance of the educational practices carried out in these spaces.

We identified an absence of a significant gap of information on the following (i) the degree of curriculum alignment of EOC programs with country-specific curriculum parameters, (ii) learning assessment processes, (iii) the professional qualifications of staff involved in EOC initiatives, and (iv) children’s school needs in terms of accessibility, inclusion, and safety. Nevertheless, the variety of mapped practices can contribute to advancing discussions about good EOC practices and thinking about ways to its accreditation.

Regarding accessibility and safety, we identified important gaps to rethink the spaces for EOC to expand discussions about accreditation. For example, multiple languages can help students who have not yet mastered the local language, such as refugees, to understand the content offered. In addition, the "Structure for hearing and/or visually impaired children" is fundamental for youth and the public also involved in education outside the classroom (e.g., teachers, educators), just as the wheelchair - fundamental for people with physical disabilities or reduced mobility. When analysed from the perspective of an educational-orientated project, the absence of accessibility features has a clear curricular impact, as it alienates part of the public from a whole experience and undermines the experience of all visitors, as they are in a less diverse environment.

The implications of this mapping study suggest that a more explicit connection between the information found on EOC organisations' websites and national curricula can facilitate the utilisation of these spaces by schools ate future accreditation processes. Although inclusive and diverse in terms of geographical contexts, our mapping has some limitations identified throughout analysing and synthesising the data. For example, we identified that works in Geography education (which also sometimes includes Geology or Geoscience and is treated as a separate subject in some curricula, such as in Spain) also have rich literature, particularly on field trips. Another limitation is in the language of the search. Actively searching for new references in the national languages could further enrich the data, better reflecting each country's reality of the EOC field. Despite these limitations, the scope (e.g., it includes papers from different European countries), and the uniqueness of this mapping bring contributions to the EOC field.

Acknowledgement

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Wicked Heritage in Informal Learning: Early Childhood Sensory Science Exhibitions

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The World faces great environmental challenges in the form of "wicked" problems such as toxic waste, resource extractivism and collapsing ecosystems. This paper contributes to understanding how we can communicate this wicked heritage to children through the exhibition medium. It is taken as a premise that understanding wicked problems depends on scientific understanding and that a good way to achieve this is through interdisciplinary STEM Education. Informal learning environments have a great potential in communicating scientific knowledge to the public, both through out of school visits and non-formal experiences. The aim of the paper is to address how to communicate toxic heritage and similar wicked legacies through the development of aesthetic and sensory experiences in informal learning environments. The paper draws on research from a pop-up STEM early childhood sensory science exhibition, located and developed at University of Southern Denmark in 2022. The design of the exhibition was research-based, drawing on theories of tidalectic curating, Conceptual PlayWorlds, STEM-pedagogy and early childhood science experience.

Keywords: Experience, science education and communication, curating wicked heritage

Introduction

Waste has always been a starting point for research and communication about cultural heritage. As Buser (2016) argues, waste is a widely accepted and appreciated part of cultural heritage, considering that a kitchen midden where reindeer hunters left the bones of their prey, gives us valuable insight into how lives were lived. We still care for these cultural heritage sites and preserve them for the future. *"The thesis put forward here is that waste, which is an anthropogenic product, should also be regarded as a form of cultural heritage, even if this legacy primarily carries negative traits and in fact represents a burdensome heritage. This is an onerous legacy, which is clearly in contrast to the great cultural achievements of mankind we are proud to extol, yet like any other work of art, reflects great human and cultural activities."* (Buser, 2016, p. 10). The onerous legacy we create right now is waste piles, polluted lakes, and plastic ocean gyres – as well as invisible heritage: endocrine disrupters in food chains and dangerous chemical compounds in all our everyday products. All the above are wicked problems, first introduced by Rittel and Webber in 1973 (Rittel & Webber, 1973) and often addressed in science education, as science plays a key role in navigating these problems (Achiam *et al.*, 2021). These wicked problems are systemic problems with a complex network of factors that makes them impossible to solve (Meadows, 2008) and dealing with them needs a transdisciplinary approach. In this paper we propose Wicked Heritage as a term that encapsulates the intertwinement of our lives, our societal form, our way of living in Western, industrialized, globalized, techno scientific societies with extraction, lack of care and trails of havoc. It is not just about the wicked problems themselves and the state of our natural environment, it is also the wicked systemic errors of unforeseen events and unpredictable consequences. It is about the legacy we leave our children. *"Wicked Heritage is the whole damn mess we have inherited. It is the mess we live with and the mess we pass on to future generations."* (Svabo, personal communication, 2023).

In this paper we ask: How do we communicate Wicked Heritage to Early Childhood (EC), in a responsible way? We, as researchers and educational developers, have an obligation to educate children in sustainable behavior and dealing with the crises of the world, but we also want them to be age-appropriately introduced to the wicked problems they inherit as a wicked legacy – problems they will have to deal with and try to participate in handling in the future, without experiencing helplessness, as is a common problem in education for sustainable development (Ojala, 2017).

Wicked heritage can be understood through scientific understanding, and research indicates that interdisciplinary Science, Technology, Engineering and Mathematics (STEM) is a good way to develop such understanding (Larsen *et al.*, 2022). Informal learning environments and out-of-school visits bear a great potential in communicating complex wicked problems such as toxic waste (Achiam *et al.*, 2021). However, to create an experience with an environmental theme that changes people's attitudes, the experience needs to affect both cognition, emotion, and senses (Hansen *et al.*, 2014), and such an experience must be age appropriate (Miller, 1996).

Research Method: Design-based Research

The exhibition, *Ocean*, was developed and carried out in September 2022 at the University of Southern Denmark as part of the science education development project LabSTEM. It was a pop-up exhibition targeted children aged 0-8 years old and covering early childhood science education. 100 children in daycare, kindergarten and primary school participated in a total of seven visits, one hour each, with their pedagogues and teachers, during the four days, the pop-up exhibition lasted. Three science communicators facilitated the exhibition experience. Qualitative data were collected through participant observation and photography as well as logbook reflections and a post exhibition/event evaluation. The development process, exhibition design and evaluation, are described in a documentation report (Svabo *et al.*, 2023a). The pragmatic grounding of the project was a science festival in September 2022. The exhibition concept was theoretically underpinned and developed with point of departure in previous research on tidalectic curating (Hessler, 2020) and the conceptual PlayWorld model for STEM early childhood education (Stephenson *et al.*, 2021).

The problem posed in the exhibition was a collapse in the food chain in a local coastal area. A problem which is an onerous legacy, we pass on to our children if we do not act. Due to overfishing, there are too few large fish (*cods and trouts*) to eat *crabs* and therefore crabs eat too many *little fish* that hence never grow into being *big fish*. This is a systemic and cyclic food chain problem and may seem like an easy issue to explain but is actually a complex problem to understand for a child aged 0-8. What did the exhibition consist of? Among the exhibition elements were tubs with *seaweed, sand and stones*, a small model of a *reef made from beach stones*, a child sized model of a reef made from pillows and a tunnel, *toy fish* and other ocean animals and *costumes as porpoises, seals, crabs, and flatfishes*. Digital media were a TV with a "*Fish Kindergarten*" streaming live video from the ocean, and a soundtrack with *sounds normally found at the beach*. In the center of the exhibition were a 2D-model of the *Earth* and a 3D-model of the *Moon*. The exhibition was the second iteration of designed STEM sensory exhibitions for early childhood and the researcher-exhibition designers drew on the research results from the previous exhibition 'Forest' (Svabo *et al.*, 2023b) as well as visits to both an aquarium and a nature center and the development process followed the model for Design-Based Research (Reeves, 2006).

Figure 1. Children, dressed in costumes enacting the movement of a wave in cooperation with their pedagogue. Photo: Robert Wengler.

The exhibition visit started with a narrative, *a story*, for both children and adults to enter the imaginary world, *the ocean*. The exhibition communicators were *dressed up as waves and sand* as a way of involving them in play activity. This is a step in the Conceptual PlayWorld model (Stephenson *et al.*, 2021). The communicators used different performative actions to simulate how the ocean sways back and forth, inspired by tidalectic curating (Hessler, 2020). In the narrative at the beginning of the visit, the children helped characters "*Wave"* and *"Sand" hide small toy fish in an artificial stone reef*, as little fish would do in nature. This will keep them safe from crabs.

Preliminary Findings: What Did We See?

With the appropriate Ethics Consent Forms in order, we as *design-based participatory researchers and communicators* observed all visits to the exhibition and found that the exhibition design fostered play and willingness from the children to interact with the exhibited problem. We observed that the children enacted what it was like to be a big or a small fish, by putting on costumes and interacting in play, hunting for prey, simulating the food web cycle of the exhibited local marine environment. Children used the bins with seaweed, sand, and stones to hide small toy fish and they played tidal patterns with each other and with characters "Wave" and "Sand". Observations also show that the children emotionally related to the little fish. Some of them carried the fish in their pocket during their whole visit. By introducing the children to the main problem, the food chain collapse, they interacted with the exhibition elements in their play with this. We observed the children talking to each other about the problem posed in the exhibition, about the food web, and wearing costumes, they enacted life in the ocean. From these observations we could see that in the interaction between children and exhibition, the children addressed the problem of food chain collapse from a child's perspective and enacted actions that would help ecosystem balance: creating microclimates for small fish to hide in.

Figure 2. Children hiding each their toy fish in the stone reef, reenacting the hiding of fish prey in nature. Photo: Robert Wengler.

Discussion: A Responsible Communication of Wicked Heritage

An explicit goal of the exhibition was to address environmental themes, to expand the children's science-based understanding of the ocean, and to work from an ethically and pedagogically responsible stance in relation to the degree of complexity the children were presented for and asked to comprehend (Høegh *et al.*, 2022). A central aspect of a STEM approach to science education is to work with real-world issues. We wanted to do this and be sensitive towards the age group and not pile another layer of communication about plastic waste and toxic heritage on the shoulders of younger generations. Inspired by Ojala's (2017) hope and agency through thinking and practice, the opportunity for children to act as individuals in the exhibition and engage in play that helps solve the problem with the food chain collapse, is beneficial, giving them agency in the situation, through practice. Some of the most interesting exhibition elements for creating agency was the artificial reef and toy fish, costumes and child-sized reef made from pillows and a play tunnel. These elements invited children to reenact processes in the ecosystem in interaction with science communicators and pedagogues. For the children to experience this agency it is very important to create an aesthetic, sensorial spatial play-world mimicking the real-world it represents (Stephenson *et al.*, 2021).

Conclusion

The aim of this paper was to address how we can communicate about wicked legacies through the development of informal learning environments and aesthetic and sensory experiences. This is a challenging theme to communicate – and even more challenging when the participants are aged 0-8 years old, i.e early childhood. We propose that working with informal learning environments, for example exhibitions, may be a route. Sensory exhibitions are interesting spatial designs in which to work with real-world issues, providing arenas for practicing engagement for societal change and an opportunity for experiencing both failure and success through play, as well as experiencing other's success in performing challenging tasks (Ojala, 2017). This can increase the children's self-efficacy. Based on this, we have created a design-based research project constructing and evaluating the exhibition *Ocean* for early childhood. This paper contains a preliminary sharing of our research and design, with a view to future publications and development.

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Identifying the Aims of Science Shows

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Science shows are widely used in informal learning contexts, such as science centres, as an important way to communicate science. In order to properly evaluate science shows, it is necessary to identify their key aims. In 2023, CERN, the European Organisation for Particle Physics, opened a new education and outreach facility, CERN Science Gateway, which hosts regular science shows. Therefore now is the perfect time to establish the aims of the science shows that are presented. Here, prioritisation tasks are used to examine the views of participants from two expert groups, in relation to the aims of science shows. The results suggest that affective aims, such as engagement and curiosity are considered to be more important aims of science shows than cognitive aims, such as learning and motivation, or aims relating to science capital, such as knowledge of science-related roles and science as a human endeavour. By defining the aims of science shows, it is hoped that this study will help to improve their future evaluation, both at this facility and in other contexts.

Keywords: Science show, science performance, out-of-school learning.

Introduction

Science shows, or science performances, involve one or more presenters "using dramatic techniques and demonstrations to communicate science to audiences in an engaging way" (Walker, 2012). They are widely employed in both informal and formal science learning contexts, including science centres, museums, and schools. Science shows are designed to make scientific ideas accessible and exciting, and indeed they have been found to have many positive outcomes. For example, previous studies have shown that they can increase knowledge of, and positive attitudes towards, science (Price et al., 2015; Schechter et al., 2010); entertain audiences (Cohn et al., 2001); improve understanding of how scientists work (Carpineti et al., 2011); and enhance behavioural engagement (Walker, 2012). In many contexts there is evidence that "science performance, done well, can lead to increased learning, improved cognitive and affective outcomes, and behavioural changes" (Austin and Sullivan, 2018, p.10). But what is the main purpose of science shows? Despite the use of science shows in many contexts, and their reported positive outcomes, there is little consensus as to the main aims of science shows.

Science show developers use various aims as the basis of their shows. For example, in Good Vibrations, a show on the physics of sound, Derek Fish proposes *learning* as the main aim (Fish et al., 2017), whereas at ScienzATeatro, *motivation* is deemed more important, as *motivation* is a prerequisite to learning (Carpineti et al., 2011). Bell (2000) believes that *entertainment* is more important than conveying information, while for Roche (2015) a science show should be at once "educational, inspirational and entertaining" (p.18).

In October 2023, CERN, the European Organisation for Particle Physics, opened a new education and outreach facility, CERN Science Gateway, to inspire diverse audiences, instil in them a curiosity for science, and to help visitors make sense of the science that shapes their lives. Alongside the interactive exhibitions and hands-on workshops that are available, regular science shows are presented in an auditorium. To fully harness the potential of the science shows at CERN Science Gateway, it is important to set out clear aims for the shows, and later examine whether these are met so that their impact can be properly evaluated. By seeking the perspectives of two expert groups, namely *science show presenters* and *senior CERN employees*, this study will identify the key aims of science shows both in general and within the context of CERN Science Gateway.

Method

Nineteen participants from two expert groups (*science show presenters* and *senior CERN employees)* completed two prioritisation and card-sorting tasks about the aims of science shows. Participants completed these tasks individually in separate sessions. The first expert group comprised experienced science show presenters and developers from around the world, and the second, senior CERN employees with links to education and outreach. These groups were selected for their relevance; the *science show presenters* could draw on their vast experience in this field when considering the aims of science shows, and the *senior CERN employees* could comment on the aims of science shows in relation to the CERN Science Gateway context.

Members of both expert groups were asked to comment on thirteen proposed aims and to prioritise them using the MoSCoW method of prioritisation. This method directed participants to group the potential aims of a science show under the following headings: **M**ust Have [as an aim of a science show], **S**hould Have, **C**ould Have, **W**ould Not Have. Participants completed this exercise as a card-sorting activity, either with physical cards in-person, or online. The thirteen proposed aims were gathered from the literature: (1) Learning, (2) Memory, (3) Curiosity, (4) Engagement, (5) Entertainment, (6) Motivation, (7) Inspiration, (8) Sense of Awe, (9) Self-concept, (10) Scientific Literacy, (11) Science as a Human Endeavour, (12) Knowledge of Science-related Roles, (13) Knowledge about the Transferability of Science. Participants could place any number of aims under each heading but were asked not to place all aims in the same column. This allowed them to prioritise a wide variety of potential science show aims relating to cognitive and affective outcomes, and science capital outcomes.

After completing the prioritisation task, participants completed a further 'Top 3' card-sorting task in which they selected the three items that they considered to be the most important aims of science shows overall and ranked them in order of importance (first, second, third).

The quantitative data from the MoSCoW prioritisation and the top three aims activity were analysed to determine the most important aims, both overall for all participants and separately for each expert group.

Results

Results of the MoSCoW prioritisation task

The results of the MoSCoW prioritisation task indicate that affective aims, such as engagement and curiosity were rated as the more important aims of science shows, compared to cognitive aims, such as learning and motivation, or aims relating to science capital, such as knowledge of science-related roles and science as a human endeavour.

Table 1 shows the items selected as 'Must Have' as an aim of a science show by participants from both expert groups. The most frequently selected aims were Engagement (selected by 12 participants), Curiosity (11), Entertainment (11), Inspiration (11), Sense of Awe (10) and Transferability (10). Only one item was not selected as 'Must Have' by any participant: 'Science as a Human Endeavour'. The other aims relating to science capital, such as knowledge of science-related roles and scientific literacy were also not prioritised.

Table 1. Number of participants who selected each aim as 'Must Have' (N=19).

Science Show Aim	No. of Ppts (N=19)
Engagement	12
Curiosity	11
Entertainment	11
Inspiration	11
Sense of Awe	10
Transferability	10

Memory	7
Learning	6
Self-concept	5
Motivation	4
Scientific literacy	2
Science-related roles	2
Science as a human endeavour	0

Table 2 shows the aims that were selected as 'Must Have' by each expert group, and the number of participants from each group who selected this aim as 'Must Have'. Here it can be seen that although in general similar aims were prioritised by the two groups, the exact ordering of these aims was different. The results show that the senior CERN employees most frequently prioritised Sense of Awe and Entertainment, whereas the science show presenters prioritised Engagement and Transferability.

Table 2. Aims prioritised as 'Must Have' by each expert group: senior CERN employees (N = 10) and science show presenters (N = 9)

Senior CERN Employees (N = 10)		Science Show Presenters (N = 9)	
Aim	**No. of Ppts**	**Aim**	**No. of Ppts**
Sense of Awe	8	Engagement	7
Entertainment	8	Transferability	7
Inspiration	6	Curiosity	6
Engagement	5	Inspiration	5
Curiosity	5	Learning	4
Memory	4	Entertainment	3
Transferability	3	Memory	3
Self-concept	2	Self-concept	3
Motivation	2	Sense of awe	2
Learning	2	Motivation	1
Scientific literacy	2	Science-related roles	1
Science-related roles	1		

Results of the 'Top 3' aims card-sorting task

Table 3 shows the items selected as 'Top 3' aims by all participants from both expert groups. The aims most frequently included in the 'Top 3' are: Curiosity (selected by 9 participants), Sense of Awe (9) and Engagement (7). Two items never selected within the 'Top 3' were Science as a Human Endeavour and Motivation.

Table 3. Number of participants who selected each aim within their 'Top 3' (N = 19)

Science Show Aim	No. of Ppts (N=19)
Curiosity	9
Sense of Awe	9
Engagement	7
Memory	6
Entertainment	6
Transferability	6
Learning	4
Inspiration	4
Self-concept	4
Scientific literacy	2
Science-related roles	2
Motivation	0
Science as a human endeavour	0

When considering the distribution of these items (Table 4), we can see that the two expert groups have prioritised the aims differently. Again the senior CERN employees have rated Sense of Awe and Entertainment most highly, whereas the science show presenters have prioritised Curiosity and Engagement.

Table 4. Aims selected and ranked in the 'Top 3' by each expert group: senior CERN employees (N = 10) and science show presenters (N = 9).

Senior CERN Employees (N = 10)					Science Show Presenters (N = 9)				
	Ranking					Ranking			
Top 3 Aims	1st	2st	3st	Total	Top 3 Aims	1st	2nd	3rd	Total
Sense of Awe	2	5	0	**7**	Curiosity	4	2	0	**6**
Entertainment	2	2	1	5	Engagement	5	0	0	**5**
Curiosity	1	1	1	**3**	Inspiration	0	3	0	**3**
Transferability	2	0	1	**3**	Transferability	0	1	2	**3**
Memory	0	0	3	**3**	Memory	0	0	3	**3**
Engagement	1	0	1	**2**	Learning	0	1	1	**2**
Learning	1	0	1	**2**	Sense of Awe	0	1	1	**2**
Self-concept	0	1	1	**2**	Self-concept	0	0	2	**2**
Inspiration	1	0	0	**1**	Entertainment	0	1	0	**1**
Scientific literacy	0	1	0	**1**					
Science-related roles	0	0	1	**1**					

Discussion

Science shows are used in many contexts as an important way to communicate science. Therefore it is necessary to carefully consider their function and purpose, by identifying clear aims. In this study 19 participants from two expert groups, namely experienced science show presenters and senior CERN employees, prioritised thirteen proposed science show aims stemming from the literature. The experts also selected their 'Top 3' aims and ranked them in order of importance.

The results from both prioritisation tasks reveal a generally shared emphasis on affective aims, such as Engagement, Curiosity, and Sense of Awe, as the most important aims of science shows. They also highlight the expert's desire for science shows to be entertaining (Entertainment), and for the science to be made relevant for the audience, by linking it to everyday life (Transferability).

The aim most frequently selected as 'Must Have' across all participants was Engagement, indicating a strong consensus on the importance of engaging the audience. This aligns with the fundamental goal of making science shows captivating and interactive. Engagement was particularly emphasised by the science show presenters, with 5 (out of 9) ranking this as their top aim overall. Transferability was also prioritised highly by the science show presenters, indicating that this group in particular have a desire to make scientific concepts transferable, and to create shows that not only impart knowledge but also facilitate the application of that knowledge to real-life scenarios. In contrast, two aims more highly prioritised by the senior CERN employees were Sense of Awe and Entertainment. Sense of Awe was particularly highly valued by this group, with 7 (out of 10) participants ranking it first or second within their 'Top 3', suggesting an appreciation by this group for the potential of science shows to evoke wonder and amazement. However, this was not as strongly indicated by the science show presenters, where only two participants ranked it within their 'Top 3'.

Taken together these findings suggest that the senior CERN employees want to entertain the audience and provide a 'wow' factor by creating a sense of awe, while the science show presenters are more interested in engaging the audience and showing them how science relates to their everyday lives. Curiosity and Inspiration were also seen as key to a substantial number of participants, indicating a desire for science shows to spark curiosity and stimulate creative thinking. While not as universally prioritised, participants from both groups also selected Memory as an important aim, indicating a recognition of the role science shows can play in creating memorable experiences. Perhaps surprisingly, given the emphasis on learning in previous studies (e.g. Fish et al., 2017 and Carpineti, et al., 2011), Learning was not selected as a key aim by many participants, suggesting that while learning is important, science shows might not be the best place for this learning to take place. Other aims, such as Self-concept, Motivation, Scientific Literacy, Knowledge of science-related roles and Science as a human endeavour were selected by very few participants, suggesting that they are not seen as a primary focus for science shows.

Investigating the way in which science shows can affect audience motivation, Walker (2012) found that curiosity was an effective motivator, whereas "prior experience and prior knowledge, and cognitive learning were of secondary importance" as motivational features. The finding, therefore, that affective outcomes such as engagement, sense of awe and, to a lesser extent, curiosity are considered the most important aims of science shows is generally in line with the research available.

One limitation of this study is in the composition of the two expert groups. One group of experts, the science show presenters were selected from around the world, therefore there is a vast diversity in their backgrounds, experience, and the contexts in which they present science shows. While it is hoped that by selecting participants from a broad range of contexts, many of the potential views will be captured, it may also mean that some results may be less relevant to this specific context. On the other hand, the senior CERN employees, were selected for their explicit links to CERN Science Gateway. Therefore, their results may not represent the views of those in other informal science learning contexts. Furthermore, no audience groups were included in this study, therefore additional studies would be needed to include the views of the audience groups who will come to see the shows. Although this is a limitation, on the other hand, having the perspectives of these two diverse groups is helpful in highlighting key aims and different sets of priorities. Establishing the aims of science shows is a much-neglected area. By identifying what two expert groups perceive to be the main aims of science shows, both generally and in the specific context of CERN Science Gateway, this study provides a platform for the subsequent systematic evaluation of such shows. This will enable better design and evaluation of future shows and increased positive outcomes for the audiences that attend them.

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Teaching Physics Concepts & Nature Of Science Tenets During The Participation In A Robotics Competition

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Twenty High School students, working in seven groups at an after-school club and a STEM center, were prepared to participate in a National Robotics Competition in Greece. It is a STEM project, applied in an out-of-school environment, where they needed to design and build their own robot, that performed specific tasks. Through this 6-month process we also taught physics concepts, integrated nature of science tenets into the instruction and developed soft skills. Results are analyzed through discourse analysis, a nature of science questionnaire, a rubric that measures the soft skills development, and classroom observations. The study pointed out that students after the intervention have a better understanding of physics concepts, even for ones they were not taught yet, and they developed their soft skills to a great degree. As for nature of science tenets, it was possible to include them in the sessions only during the aftermath analysis of the competition, Similar projects are an ideal opportunity to deepen students' understanding in physics and develop their soft skills.

Keywords: physics concepts, nature of science, educational robotics, STEM project

Introduction – Theoretical Background

STEM education is a trend in science and technology education, applied at in- and out- of-school activities. It is student-centered, focusing on real world problems and authentic learning environments (Millar, 2020), enabling the development of different literacies, and implies inquiry-based learning, design-based learning, and problem-based learning. (Holmlund et al, 2018; Falloon et al, 2020). Part of STEM Education is Educational Robotics, that refers to the use of robots, either as a tool or as a means, in teaching practice. Participation in robotics competitions has become popular in the last few years (Theodoropoulou et al, 2023). The development of conceptual understanding of physics concepts that are relevant to the robot's motion (Church et al., 2010; D'Amico et al., 2020) or Newton's laws (Ferrarelli & Iocchi, 2021) is another goal to achieve, that activates students' participation, empowers their understanding and efficacy, and relates the theory to practice.

Soft skills refer to those social and emotional skills every citizen and worker of the 21st century needs to possess, to better face contemporary changes. They are not directly connected to specific tasks but are useful for any task in a human's social or working life. STEM education characteristics enhance the development of soft skills at all levels of education (Thibaut et al., 2018). Communication, collaboration, creativity, and critical thinking (the 4C's) are the soft skills cultivated in many STEM and physics programs (i.e., Stehle & Peters-Burton, 2019; Khoiri et al., 2021).

In contemporary science curricula, teaching refers to the inclusion of a) content knowledge, b) inquiry methods, and c) the understanding of how science works, meaning the nature of science (NOS) (Bell, 2008, pp. 13-18). Since this article is about implementing science concepts in an inquiry-based learning STEM project, it is interesting to study whether NOS aspects can be embedded in the project and whether students understand them. We use the Lederman model, that studies the aspects of Nature of Scientific Knowledge (NOSK) (Lederman et al., 2014) and the aspects of Nature of Scientific Inquiry (NOSI) (Lederman et al., 2013).

Methodology

This work is about the preparation process of twenty high school students for their participation in the National STEM Competition, organized by WRO Hellas (see next paragraph), during school year 2022-23. The preparation process started in mid-September 2022 and lasted until the end of March 2023, when the final phase of the competition took place.

The research questions are 1) whether they understand physics concepts better, 2) how they develop soft skills, and 3) whether it is possible to understand NOS aspects through their involvement in the project. It is action research with a mixed methods approach, since both qualitative and quantitative data are used. The first author attended all sessions as a supplementary instructor, observing and discussing with students.

The tools used regarding physics concepts are: written reports as pre-test, interviews, and classroom observations as post-test, analyzed in NVivo. Regarding the soft skills development assessment, we created a rubric, shown in Table 1, depending on what students achieve. The development of each student group per skill was recorded monthly by the first author.

Table 1. Rubric to measure the soft skills development

	Below Standard	Approaching Standard	Standard	Above Standard
Communication	Cannot communicate on what to design and build	Strong instructor's intervention needed to communicate their ideas	Instructor's intervention needed to communicate their ideas	All members express their opinion and decide what to do
Collaboration	Cannot decide on the role of each member and disagree with the result of each stage	They define the roles of each member, but some contribute more than others	All members of the group contribute to the project fairly	Every member has their own role, cohesive with the roles of others
Creativity	Cannot find ideas to design the robot without the intervention of the instructor	They have ideas, but do not know how to implement them without the instructor	They find difficulties to understand what to do, they need little help from the instructor	They design & build each stage of the robot by themselves, original designs
Critical Thinking	Cannot define the problems they have to deal with	They partly understand the problems, they analyze facts, but cannot define their priority	They define the problems, they evaluate and interpret the facts, but cannot manage to resolve the problem	Define the problems and manage to solve them by themselves, develop a strategy and follow it

Regarding the understanding of NOSK and NOSI aspects, it is known from the literature that in our country students have naïve views for most of them (Koumara & Plakitsi, 2020). As a pre-test, students answered the SUSSI questionnaire (Student Understanding of Science and Scientific Inquiry) (Liang et al, 2008) chosen for its Likert-type answer options, whereas interviews and discussion in the plenary sessions were used as post-test. Regarding the project, the aspects that could be discussed are that scientific knowledge is creative and subject to change in the light of new evidence, that procedures are guided by the question asked, explanations are developed from data and what is already known, investigations begin with a question), and procedures influence the results. Students' demographics are shown in Table 2.

Table 2. Students' demographics on each group

Group	Origin	Grade/age	sex	Level of experience
1	After school club	All in 10^{th} grade/15	1 boy/2 girls	Experienced
2	After-school club	2 in 10^{th} grade/15, 1 in 8^{th} grade/13	2 boys/1 girl	Experienced
3	After-school club	All in 9^{th} grade/14	2 boys/1 girl	Experienced
4	After-school club	All in 7^{th} grade/12	1 boy/1 girl	Beginners
5	After-school club	2 in 8^{th} grade/13, 1 in 7^{th} grade/12	3 boys	2 beginners/1 experienced
6	STEM center	2 in 9^{th} grade/14, 1 in 10^{th} grade/15	2 boys/1 girl	Experienced
7	STEM center	All in 9^{th} grade/14	3 boys	experienced

Identity of the competition

WRO Hellas is the local partner of WRO (World Robot Olympiad) Association for Greece, that hosts the preliminary competition for the groups that will represent the country in the WRO final (https://wro-association.org/). Apart from that, it also organizes a national STEM competition, to promote STEM and robotics in the Greek educational community. There are categories from kindergarten to high school. Students that participated in our work took part in the Regular category, where each group builds their own robot that moves in a field and does specific tasks, according to the rules, using the Mindstorms or Spike Prime LEGO® sets. This year, the robot had to create a tic-tac-toe, of random orientation (horizontal, vertical, diagonal), specified by a color-code at the beginning of each round.

Discussion

Physics concept learning

The studied concepts are "inertia" and "friction." At the beginning of our sessions, all students were requested to write down the definition of each concept, applying examples in everyday life and how they think they affect their robot project. Regarding "inertia" the 7^{th} grade students were not aware of the concept. The others defined inertia based on their textbook's definitions, gave the school textbooks' examples and all but one could not find any connection to their project. As for friction, they all described it as the force that opposes motion, correlated it only with sliding friction, naming examples from their textbooks, and predicted that it would appear in robot's motion.

Soon after building their prototype and starting their trial in the game field, they came across the effect of the concepts. First, they 'discovered' inertia, since their robot did not stop precisely at the point, they had it programmed, but a little further, as mentioned in the interviews by six groups. Four of the groups fixed the problem by lowering the speed, and the other two by decreasing the volume of the robot. The last group did not encounter this problem in linear motion, but inertia as appeared when the robot turns while moving:

> "In a sharp turn it could not get back into a straight line, instead the rear part kept turning. Even if [the robot] goes off for a few degrees is a problem because we need precision. We dealt with this by lowering the speed even further and adding wheels instead of marbles to increase the friction at the rear point."

All students correlated the term to sliding friction, though only the five 10th grade students were aware of static friction. All students learned about this other kind of friction when six groups designed a robotic arm that used rubbers to "keep the cubes fixed in the robotic arm during motion."

Regarding the motion of the robot, some groups wanted to increase friction, and others wanted to lower it:

> "As for the wheels, we needed lower friction, so we rejected the smaller [wheels] that are thicker, without a big radius, because the motor is worn out. The thickness affects friction, and when the robot turns, adhesion is different,"

mentions students from Group 6. Group 1 discussed the marbles they used at the rear part of the robot that "allowed [the robot] to move faster. The marbles have lower friction, and the rear wheel drive helps to align faster after a turn." On the contrary, group 3 votes against marbles in the rear part of the robot because *"* friction is not high, and it cannot align after a turn. All our problems stopped when we used the bigger wheels instead*"*. Though, this group did not use rear wheel drive. Finally, Group 5 notes that

> "we did not have time to build a robotic arm, so we did a construction that drags the cube. But this increased friction. So, we could not do much mechanically about the speed, so we tried through programming to increase the power on the motors".

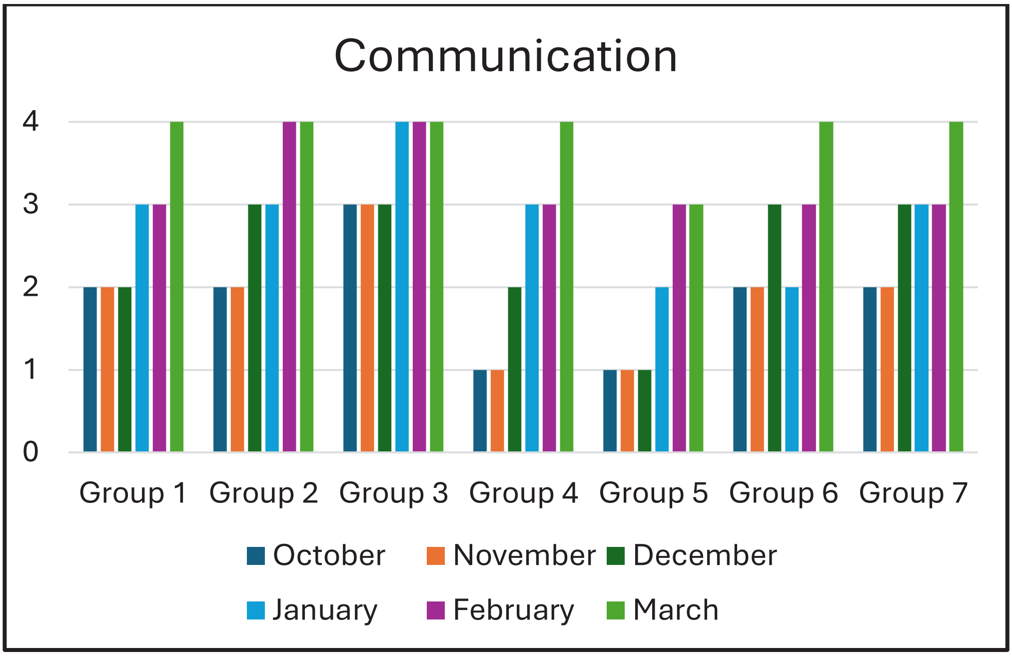
When they described their robot to their peers they used, all groups used scientifically correct reasoning and concepts.

Soft skills development

According to the rubric described above, the researcher that did the observations, reported monthly on how the soft skills of each group are developed, considering her notes during the daily observations, and her discussions with the two main instructors. The results are presented in Figures 1-4 for each skill.

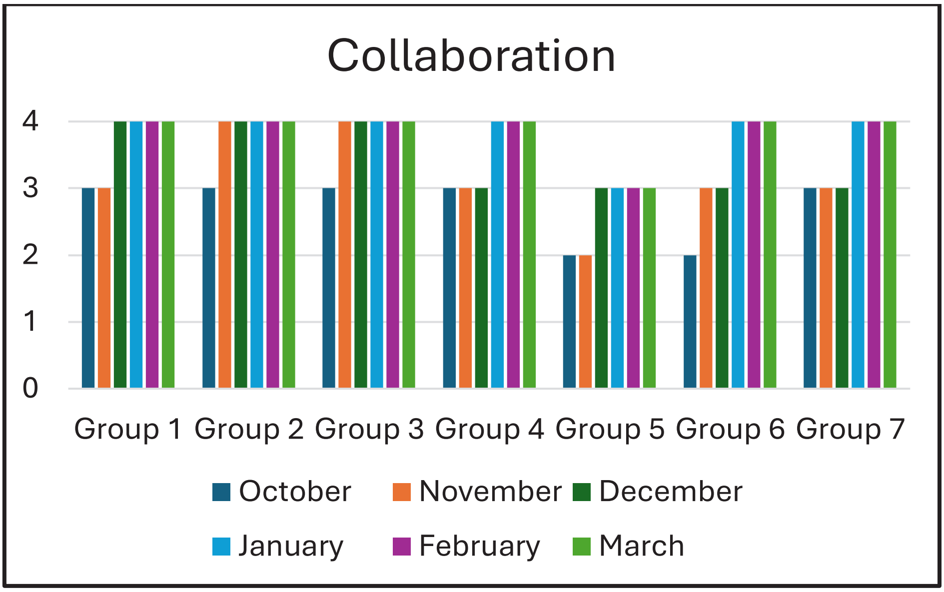
Regarding communication (figure 1), only group 3 started with a standard score, because students knew each other well and had worked on other projects. The beginners' groups 4 and 5 lacked knowledge and this frustrated them. Group 6 was a new group and needed some time to teach each other. By the end of the project, all groups reached the highest score, apart from group 5, that had difficulty communicating for most of the project, having an instructor by their side for whole sessions.

Figure 1. Development of the communication skill from October to March for each group



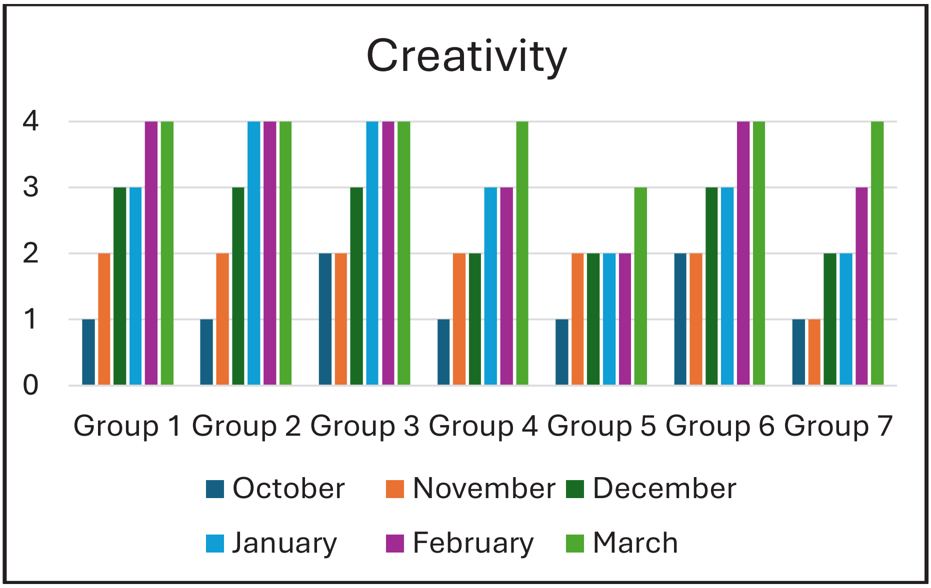
Collaboration (figure 2), started at the standard level (groups 1, 2, 3, 4 and 7) and approached standard (groups 5 and 6) scores, because all students were willing to help. Group 6, as a new group, needed some time to assign roles to its members, whereas group 5 dealt with their communication difficulties problems. Most groups excelled in this skill fast, i.e., their members found their roles quickly.

Figure 2. Development of the collaboration skill from October to March for each group



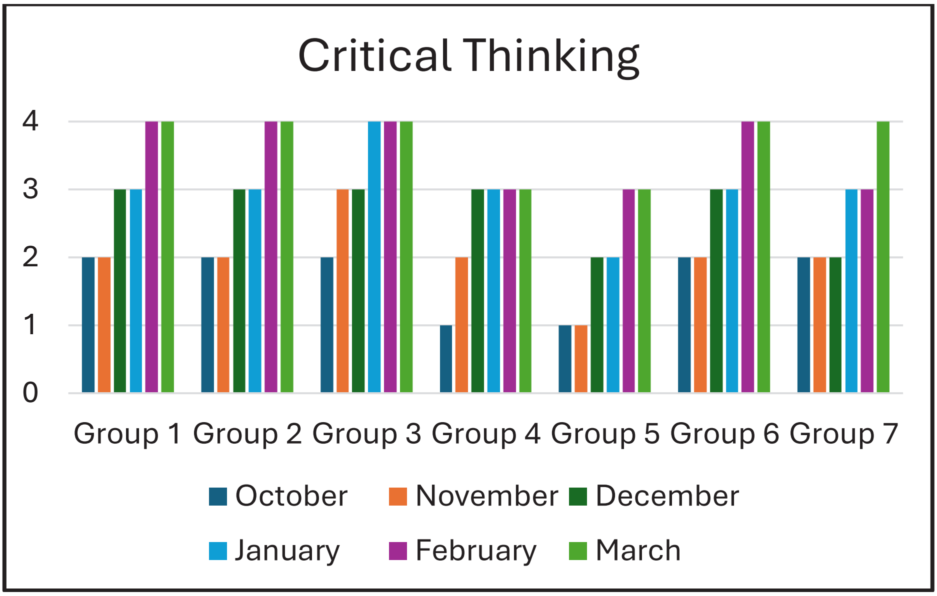
As for creativity (figure 3), all groups but one started from the lowest score. Students did not have ideas on how to design their robot and tried to find designs from the internet. Group 6 had experience from similar competitions, so they tried to adjust an older construction. It was the only group that did not search for a solution online. By the end of the first month, all groups apart from the 7th one, had comprehended the tasks and adjusted the prototype robot to their needs. All groups used try-and-error during the construction, tried random solutions that worked, adjusted both the program and the construction so the robot does as many tasks as possible. All groups note that by the end of the preparation process the initial robot had little similarity with the final one.

Figure 3. Development of the creativity skill from October to March for each group



Regarding critical thinking (figure 4), it started below standard for the beginners' groups and approaching standard for the advanced groups. It was the skill the instructors helped the most to develop, since it was strongly linked to the cognitive content. From the beginning of our sessions, we had discussed in the plenary session that a project like this needs to be separated into smaller problems and students defined what needs to be done each time. The beginners' group lacked necessary knowledge to understand the tasks and deal with them. The other groups managed to understand the problems but could not define the priorities. All groups needed guidance from the instructors to overcome their difficulties. Developing their critical thinking skills to the top score meant that the groups were well-aware of their project and could resolve any issue by themselves (during the competition, the instructor cannot interfere).

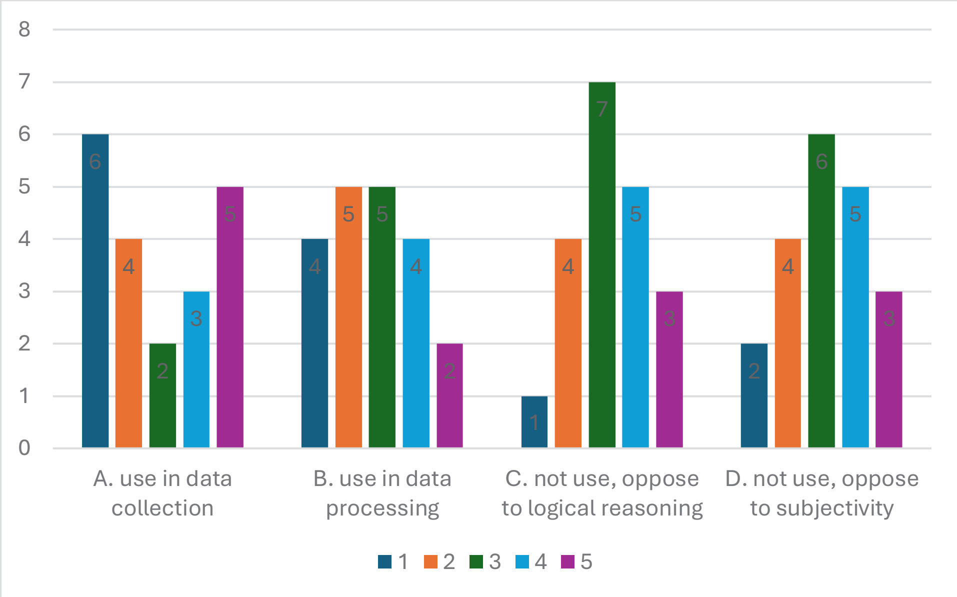
Figure 4. Development of the critical thinking skill from October to March for each group



Teaching NOS tenets

In the beginning of our sessions, students answered the SUSSI questionnaire. We analyze the creativity tenet that is studied in our project. The results about creativity and imagination in scientific investigations are shown in Figure 5. Students answer in a 5-point Likert scale, 1 being "strongly disagree", 5 being "strongly agree". The four sentences are: a) Scientists use their imagination and creativity when they collect data, b) Scientists use their imagination and creativity when they analyze and interpret data, c) Scientists do not use their imagination and creativity because these conflict with their logical reasoning, and d) Scientists do not use their imagination and creativity because these can interfere with objectivity. In Figure 5, ten students do not believe that scientists use their creativity in data collection, but another eight agree with that opinion. Nine students also do not believe that scientists use their creativity in data processing, but only two strongly agree with that opinion. As for not using creativity (questions c and d) the majority has neutral opinions. Consequently, some students believe that scientists use their creativity in data collection but have neutral to negative opinions that creativity and imagination are used anywhere else.

Figure 5. Results on using creativity and imagination in scientific investigations (SUSSI instrument – October 2022)



During the preparation process, students were interested in completing their projects and using their robot to accomplish as many tasks required by the competition as possible. Therefore, they were not willing to discuss about any issues not related to their project. So, our next chance to discuss NOS tenets was after the end of the competition, in the first sessions of April, when discussing on the aftermath of the whole experience. Results are organized in Table 3. Students took part in the discussion, and about half of them participated actively. However, there is a need to find another way to engage them in epistemic issues throughout the preparation of the project (see future work).

Table 3. NOS tenets embedded in the project

NOS tenet	How it was embedded in the project
creative	As in their project, scientists need to be creative during their research, and use their imagination to suggest innovative solutions in all stages of the investigation.
subject to change in the light of new evidence	Just like students get better results when using more accurate coding blocks or using two color sensors instead of the one in line following setting, scientists get more accurate data that may change the way they see the world. They can always reinterpret data, and there is no such thing as an "accurate experiment," since it is the aim, always to get more accurate data.
procedures guided by questions	All groups need to work on exact, coherent, and consistent problems/questions. Students had understood that through their project in an implicit approach.

explanations developed from data and previous knowledge	Students need to comprehend the behavior of their robot based on their observations and their previous knowledge. Based on that, they can make improvements. Also, they understood that implicitly through the project.
investigations begin with a question	As all groups need to define the problem and ask questions on what they need to work on, so do scientists. That was understood implicitly through the project.
procedures influence results	According to the design of each group's robot, physics principles affect the robot's behavior differently. Students had not realized that before we all discussed in a plenary session and each group described the problems they faced.

Limitations of the project

The interaction and behavior of students in their respective groups were also done outside the after-school club and the STEM center. Consequently, it was not possible to record every interaction, thought, and behavior they had.

Future work

To activate the students more and enhance their collaboration skills with their peers more, we are thinking of introducing the engineering design process. Students need to design on paper, present their findings and thoughts at the beginning of the session once per two weeks and discuss it in the plenary.

Conclusion

From all the above, it is pointed out that all research questions were studied and are positively answered. The twenty students, during their 6-month preparation to participate in a robotics competition, understood experientially inertia and friction, and discovered the parameters they depend on in the real world. They developed soft skills while working in their groups, to achieve their goals, and – to a lower degree – comprehended some epistemological aspects of science. This year, half of the students participated again in the same competition (11^{st} grade students did not continue because they started their preparation for the National University entrance exams) in slightly differently arranged groups. Eight new students are added, both in the after-school club and the STEM center. Instructors use the engineering design process to guide students more effectively. Last-year students were more confident and adjusted very quickly to the requirements of this year's tasks. Also, five of them claim that their performance in physics has improved significantly.

Acknowledgement

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The 15th Conference of the European Science Education Research Association (ESERA)

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