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Part 8 / Strand 8

Scientific Literacy and Socio-scientific Issues

Editors: *Antti Laherto & Eliza Rybska*

Part 8. Scientific Literacy and Socio-scientific Issues

Teaching about scientific literacy, science and citizenship education, science and media education, information literacy, informal reasoning and critical thinking, decision making, debates on socio-scientific issues (SSI), discourse communities, social dimension of science and techno-scientific practices, public engagement in science, schools', students' and teachers' engagement in socio-scientific issues.

Strand 8. Scientific Literacy and Socio-scientific Issues

Strand Chairs: *Antti Laherto & Eliza Rybska*

Introduction

Since the previous ESERA conference in Bologna in 2019, the world has changed in ways that nobody could expect. The risen crises have had and continue to have a deep influence on societies and educational systems and approaches. In the field of science education, probably the most immediate and apparent consequences apply to research and practice on our strand, "Scientific Literacy and Socio-Scientific Issues".

For years, the most central and wide-ranging socio-scientific issue for science classrooms has been the ecological crises caused by climate change. Nothing has rendered the climate emergency less acute now – on the contrary, the latest report by the Intergovernmental Panel on Climate Change (IPCC) highlighted that the phase of global warming is even faster than anticipated and the need for action more urgent than ever. Yet, in the spring of 2020, another concern took over the public discourse and schools: the pandemic caused by the novel coronavirus. Since then, the issues related to restricting the spreading of the virus, the clinical picture of the disease caused by the virus, and the pros and cons of the vaccine have constituted socio-scientific issues that no citizen can avoid facing. Aspects of scientific understanding, scientific argumentation and scientific literacy play substantial roles in these discourses, making them highly relevant to science education.

In February 2022, the pandemic stepped aside from the headlines in Europe. Russia's shocking, unjustified and brutal attack on Ukraine has caused immense suffering and anxiety. It also impacts the scope and way of thinking about socio-scientific issues. Some questions came back to us with a more significant impact, while others are new. Socio-scientific issues directly related to science education include, for example, the need to break Europe's dependency on Russian fossil fuels and find new solutions to energy production.

All these grand challenges Europe is facing in the 2020s give rise to considerations in science classrooms. What is green, responsible and sustainable energy? What does it mean to be a responsible citizen? Why are anti-vaccination movements more vigorous when we observe so many people in hospitals? Can the Anthropocene serve as a framework for science education curricula? The spectrum of questions pertaining to socio-scientific problems seems to be broadening. Addressing them in education calls for interdisciplinary approaches and explicit consideration of moral and ethical questions and values.

The twelve papers from Strand 8 in this e-proceedings capture the diversity of topics and research approaches related to socio-scientific issues. Both new and already established orientations are manifested in the following papers.

Giulia Tasquier and colleagues organised a symposium in ESERA 2021 presenting several EU-funded projects employing the concept of *open schooling* to facilitate an educational change in these challenging times. After this symposium paper, the following consists of three papers addressing science teachers' needs to support reasoning in complex socio-scientific issues. To that end, *Tom Konrad Anton* and *Christiane S. Reiners* focus on evidence-based reasoning of socio-scientific issues, *Marcus Kohnen* and *David Rott* on critical thinking, and *Jose Manuel Hierrezuelo-Osorio* and *Antonio Joaquín Franco-Mariscal* on students' emotions about socio-scientific issues. Studies on school interventions addressing socio-scientific approaches and decision-making are reported by *Miki Sakamoto* and colleagues, and *Maria Tsapali* and *Michelle Ellefson*. *Larissa Nascimento* and colleagues studied the development of biodiversity values among pre-service science teachers. *Stephanie Teeter* and *Jason Painter* explored the potential of a scientist-teacher partnership, and *Mengyao Li* examined the connection between science capital and science career intentions. Different visual methods of instruction were studied by *António Almeida* and *Rafael Sumozas,* as well as *Luiz Augusto Rezende-Filho* and colleagues. In the final two papers, *Mientje Lüsse* and colleagues report a study on a citizen science project, while *Eleonora Barelli* and *Olivia Levrini* explore the power of agent-based simulations in building analogies. We thank all authors for these contributions!

OPEN SCHOOLING IN THE (POST-)PANDEMIC WORLD: SYNTHESIS AND SYNERGIES FROM CURRENT EU-PROJECTS

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The pace of change in society, from technological innovation to global interconnectedness, has been fundamentally altering the way people live, work and learn. The increasing level of complex societal challenges of the 21st century renders urgent the need to integrate the knowledge and expertise of different societal actors, and to develop meaningful, inclusive and sustainable ways of connecting schools, universities, enterprises, civil society, governments and local communities using more innovative and open methodologies. In this scenery, from 2015, the open schooling idea started to enter the EU political horizon as a re-orientation of the role of the school and. Within the "Science with and for Society" pillar of the Horizon2020 EU Programme, the EC called for the development of new approaches to science teaching and learning, based on an open schooling approach. This symposium was orchestrated to put together different perspectives and approaches coming from four Horizon2020 projects that are developing open schooling ideas for re-imagining how school science can be rethought for steering the change in these challenging times.

Keywords: Open Schooling, Scientific Literacy, Science with and for Society

INTRODUCTION

Nowadays, even more than in earlier periods, the educational world is facing the urgency of formidable challenges (UNESCO, 2020). Indeed, in front of the increasing level of complex challenges facing society, like the pandemic and/or climate crisis, it is moving for finding innovative strategies to prepare individuals and communities to act and react to those societal changes and to be actively responsive in knowledge-based decision-making processes. Already in 2015, two reports, one from UNESCO and the other one from the EC, started to warn that complex changes and challenges in the today's world require to better understand science and technology in order to participate in knowledge-based decision-making. In particular, the EC (2015) report stated that, in order to address this issue, ways of expanding science education beyond traditional school models must be created and explored. Contextually, the report introduced for the first time the concept of 'open schooling', which is calling for a re-orientation of the role of schools. Particularly, open schooling implies that schools cooperate with other organisations to achieve community well-being and change the way science comes into the classroom. 'Openness' refers to the idea that schools have to become flexible structures, open to society and able to make a difference in the world (EU, 2015). The open schooling idea started to enter the EU political horizon related to the re-orienting the role of the school and, within the "Science with and for Society" pillar of the Horizon2020 EU Programme (WP2016-2017), the EC called for the development of new approaches to science teaching and learning, based on an open schooling approach, in which science learning processes are strongly linked to the students' participation in real-life science challenges in society, authentic research and innovation circles of inquiry.

Many open schooling practices emerging in the last years demonstrated that open schooling could have a lot of potential by representing a place where schools (in cooperation with other stakeholders) become agents of social change and community wellbeing. It offers a promising, albeit challenging, solution that requires a research-based, practice-oriented coordination to foster and support the necessary transformational action (Penuel, 2017). What are the main achievements reached out in the last years of EU funded projects on open schooling? What are the main impacts at an Institutional level? How can open schooling contribute to reimagining school science in today's world?

Within this framework, this symposium was orchestrated to put together perspectives and approaches coming from four Horizon2020 projects (all funded and started in 2019) implementing open schooling and discuss how they are re-imagining school science in answering to these challenging times.

SEAS project

To tackle the combined and interlinked challenges of human-made climate change, biodiversity loss and unsustainable consumption, society faces the need for rapid and deliberate transformation on a scale never before attempted (IPBES 2019). Education has a critical role in the struggles for a transition to an equitable and sustainable future. For science education, the challenge is to foster citizens with scientific literacies for applying and adapting scientific knowledge and methods to real-life challenges, often socio-scientfic issues, for critical and informed decision making and action for change (European Union 2015, Hodson 2003, Sadler et.al 2017). What will be important is to create and explore ways of expanding science education beyond traditional schooling models, which shall provide young and adult learners opportunities to engage in authentic science inquiry across formal, non-formal, and informal settings. It is also a matter of reflecting on the usefulness and relevance of science, thereby connecting science to beliefs, values and interests in the fostering of capacities for transformative action. Open schooling initiatives, where schools in cooperation with other stakeholders become agents of social change and community well-being, offer a promising but also challenging solution.

Throughout the process of the open-schooling approach, the H2020 project *Science Education for Action and Engagement towards Sustainability* (SEAS; https://www.seas.uio.no) project is experimenting with and developing tools for science education that explore solutions to sustainability issues, in collaboration with schools and actors in the local community. We consider tools as resources that influence practice and the ability of purpose-driven practice to engage with pre-determined ambitions. There are different types of tools, including textual objects (e.g., templates and instructions), methods (e.g., for inquiry) and tools for supporting collaboration. Tools both construe and enable practices as cultural resources serving to coordinate actions in specific ways and mediate the way collaborating partners experience and make sense of their objects (e.g., teaching for sustainability) (Jornet & Jahreie 2013).

The ambition is not only to increase scientific literacy among students, but for all actors to experiment with co-creating solutions for sustainability through how we engage in the process. Rather than treating people as “objects to be changed” in the name of sustainability, transformative change requires students, as well as teachers and people in the local community, to experience and understand how they can be agents of change. Our research question is: What role does tools take in efforts towards transformative change in the SEAS open schooling local networks?

To ensure that the SEAS’ tools and collaborative methods continue serving the participants’ and researchers’ emerging needs throughout the challenges’ implementation, a range of data sources are assessed by the local networks, including questionnaires, interviews, and ethnographic observations of learning trajectories across contexts. These assessments lead to context specific knowledge that are used for further development of the local networks’ practices, tools, and for cross-network analysis and the development of models of scientific literacies, teaching and learning, and open schooling cooperation.

A key didactical tool, LORET, represents a methodology for co-creating locally relevant themes and curricula for open schooling, for providing shared reference points for pathways of emerging learning trajectories, and for facilitating and expanding collaboration with partners outside school. It offers teacher teams a step-by-step procedure to explore and plan teaching that is engaging with and aims at developing and responding to local sustainability challenges.

cCHALLENGE is a reflexive and experimental process for transformative learning, focusing on the relationship between individual change, collective change and system change. The method is based on the heuristic the Three Sphere of Transformation (O’Brien & Sygna, 2013), and invites students and teachers to explore how change happens through changing a habit for 30 days. The change experiments allow them to notice their influence on others by sharing their stories, and to explore their own role in changing unsustainable systems and cultures.

LORET is inviting students, teachers, researchers and communities to explore the status of objects of concern and inquiry in the process of finding solutions. In this sense it is opening practices and cultures to their entanglement and non-closure. By pointing out the surplus of the object of inquiry the tool can be seen as to have a potential for transformative change and agency, and open up beyond the immediate objects and practices without implying a transformational state at which process is to arrive (no harmonizing synthesis).

cCHALLENGE is inviting students to break a pattern and explore when change is easy and when it is difficult, thus getting a glimpse of the systemic and cultural causes of problems. The students are practicing what they learn in their own lives, questioning what is, challenging the status quo, willing to look inward and act outward. The tool opens for insights into how participants construe the challenge they are confronting, and, for the teacher, students' needs for further support.

These aspects of the tools discussed are tightly connected to key aspects of open schooling: The need for enabling cooperation and negotiation of diverse perspectives and knowledge domains across institutions and settings, the need for teachers to develop interdisciplinary curriculum plans that support students learning trajectories and their use of knowledge for action, and for students to be able to engage in inquiry in real-life problems that tend to be ill-defined and complex.

SEAS findings suggest that tools can have a potential for transformative change by opening for inquiry beyond the immediate object and by opening practices and cultures to their entanglement and non-closure, and for students to break a pattern and explore and link what they were doing in their own life to societal structures, culture and deeper dimensions of change such as values and worldviews.

PHERECLOS project

The establishment of Local Education Clusters (LECs) or micro networks is the core of the Horizon 2020 project *Partnerships for Pathways to Higher Education and Science Engagement in Regional Clusters* (PHERECLOS; https://www.phereclos.eu) to explore permeable systems between formal and non-formal education and to foster Open Schooling (OS) culture. Within the project LECs are established in six pilot regions and diverse educational ecosystems around Europe and beyond. This is based on experiences from almost 20 years of Children's University programs that engagement and understanding of science, arts and humanities is a key to social inclusion and the acquisition of fundamental competencies – often described as the 21st century skills. Giving science a face through direct contact – even online, enabling reflected perspectives and also addressing the unknown as prerequisite of scientific research shall foster the inherent critical mind and the ability to assess information of children and young people (Gary & Dworsky, 2013).

PHERECLOS highlights the learnings from the piloting work in the LECs and aims to use these experiences to catalyse access to higher education, particularly for STEAM-related careers, providing benefits in a wider societal context. Young people should accumulate important experiences to raise their Science Capital (Godec, King &Archer, 2017) as key to active citizenship and critical thinking from the earliest age on.

A main challenge of PHERECLOS lies in the heterogeneous approaches to OS, STEAM Engagement and Science Capital realised in various LECs. All LECs excel through specific aims, partner institutions, and planned activities. To compare them with respect to structure and implementation processes, it is necessary to establish a shared vision how to implement educational innovations in existing structures. This is a prerequisite for deriving success factors and challenges not only for the specific LEC programs but also for OS initiatives in general. Knowledge and tools from Implementation Science (e.g. the Hexagon Tool, Implementation Plan) were used to address this demand. Templates for documenting the LECs' structure and activities in a uniform way were developed.

The main objective of the current study was to conduct a formative evaluation of the implementation of the LECs. We were mainly interested in the following questions regarding the implementation of Open Schooling (OS):

- How is the OS approach applied in the LECs? How can these approaches be described on the basis of the Hexagon Tool (Blase, Kiser & Van Dyke, 2013) at the beginning of the project?
- How do the OS approaches prove themselves in practice? What are lessons learned after one year of implementation?
- How can the Hexagon Tool be used for project reflection and steering?

For answering these research questions, LEC Templates (completed by the LECs in May-September 2020) were developed based on the Hexagon Tool, consisting of three parts: A template for the *general LEC description*. This template collects information about the aims, organizations, and activities of the LECs. One focus lies in connecting the specific aims of the LEC to the overall aims of PHERECLOS. The second template assesses the *innovation indicators*. These specify the extent to which the program demonstrates evidence, supports for implementation, and usability across a range of contexts. With the third template, *system indicators*, i.e., the extent to which a program matches the implementing site, are assessed.

Furthermore, an implementation checklist was developed to keep an overview of the implementation process and the relevant indicators, which should be filled in every half year. Similar to the templates this checklist is completed by the LEC leads: It is again based on the Hexagon tool, but in addition, implementation fidelity is also recorded, as well as successes, challenges and support needs. The results of the checklist analysis are available to the PHERECLOS consortium for discussion. They are intended to stimulate the reflection process and to identify support needs and possibilities to ensure the best outcomes of the LECs.

For answering our research questions, document analyses were carried out (templates), the checklists with closed and open questions were evaluated at three different points in time and related to another.

The results showed that the LEC templates are a useful tool to describe the various OS approaches and support the LEC's work plan design. The checklist results pinpointed topics, which could be helpful for further development of the LECs. It became clear during the second survey that the different system indicators, in contrast to the project start, are described very well. The innovation indicators provided a very good description of innovation in the second survey, but evidence for the effectiveness of the LECs related to OS, STEAM Engagement and Science Capital was still lacking. The second survey showed that implementation teams were established with stakeholders from different organisations and different perspectives. However, it was still open for some LECs how to establish and maintain coordination and communication and how to measure outcomes. These topics will be addressed in workshops and through individual consultations by our implementation experts that are part of the PHERECLOS consortium.

All in all, it can be said that the developed templates –based on knowledge from Implementation Science- have proven their worth in describing the approaches of the LECs and that the

Checklist seems to be a good instrument for the further development and steering of the LECs. Thus, Implementation Science knowledge and tools can be helpful in supporting successful implementation of OS projects.

OSHub project

The pace of change in society - from technological innovation to global interconnectedness - has been fundamentally altering the way people live, work and learn. Moreover, the societal challenges of the 21st century render urgent the need to integrate the knowledge and expertise of different societal actors, and to develop meaningful, inclusive and sustainable ways of connecting schools, universities, enterprises, civil society, governments and local communities using more innovative and open methodologies. The *Open Science Hub* (OSHub; https://opensciencehub.net) Network, a consortium of nine European partners funded by Horizon2020 EU Science & Innovation program, supports schools and local stakeholders to use research and innovation as a tool to tackle local relevant challenges and contribute to sustainable community development. Particularly, OSHubs support schools and local stakeholders to use research and innovation as a tool to tackle local relevant challenges and contribute to sustainable community development, by engaging in real-life projects that meet societal needs. Importantly, OSHubs are being established in communities that traditionally do not engage with research and innovation due to various barriers - geographical location, socio-economic status, or ethnic minority group background.

After 10 months since the beginning of the project, all local teams have started their OSHubs, as can be seen in the OSHub.Network website - under the respective Local OSHubs pages. Most particularly, OSHubs have partnered with local schools (Partner Schools section) as well as relevant community stakeholders (Local Management Board section). The Management Board consists of a group of representatives from different local stakeholder groups (schools, families, research institutes, enterprises, industry, civil and wider society) that will be involved in all key processes and decisions of the local OSHubs. In addition, OSHubs have identified preliminary challenges (Challenge and Mission section) and defined initial ideas for the open schooling projects that are being co-created in collaboration between the local OSHub teams, schools and local stakeholders. As can be seen in the website, the institutions that belong to the OSHub Management Board, the identified challenges and the open schooling projects in each OSHub are quite diverse, reflecting the different local ecosystems, but also the different nature of the OSHub host institutions (ranging from universities, to SMEs, cultural, scientific and educational institutions and municipalities), each of them with their institutional assets and networks.

In the long run, we envision OSHubs as education brokers that support schools incorporating open schooling in their daily life practices, vision and organizational structure, leading to sustainable quality of education in unison with their needs, context and local communities. In order for this to happen, it is pivotal to define shared goals with schools, aligned with their needs and priorities. Indeed, a clear observation from the last months of the pandemic, was that the OSHubs that were responding to the actual needs of schools, were the ones less affected professionally by the effects of the pandemic, and that in some cases increased their activity. As such, although, due to the pandemic, the following months are surrounded by uncertainty, we believe that schools will, unfortunately, need more support from external partners, and as such it will be a relevant time period to test the OSHub model in each location.

PULCHRA project

The Horizon2020 project *Science in the City: Building Participatory Urban Learning Community Hubs through Research and Innovation* (PULCHRA; https://pulchra-schools.eu) explores the open schooling concept in the theme "Cities as urban ecosystems" in view of creating new partnerships in local communities to foster science education for all citizens. Schools, in cooperation with other stakeholders become agent of community well-being, taken that the theme explored encompasses the natural environment, the built environment and the socio-economic environment in cities.

The overarching aim of PULCHRA project is to facilitate support actions that engage learners in meaningful real-life problem-solving situations starting as of the beginning of the second year of the project and continuing during the second and third years, within education, workplace and other learning environments. The target groups are mainly students in the age range from 12 to 18 years old, i.e., the next generation of science literate citizens, and secondary citizens, including students' parents, interested in science events. Teachers are a critical part of the Science Teams as developed within the PULCHRA project, in particular with respect to motivating students and coordinating projects. The project has given weight to engage teachers and provide them the required scientific and technical support.

An innovative part of the PULCHRA project is that participatory and activating challenges are rolled out as City Challenges supporting partnerships in local communities (schools, agents of formal and non-formal education, enterprises, industry, local administrations, NGOs, civic groups, etc.). City Challenges are supported by the City Challenges Platform acting as a hub for open schooling through the interaction among stakeholders, the communication of the schools' projects, the provision of educational material, the facilitation of twinnings and mentorships, etc.

The PULCHRA project has already demonstrated the direct links between sciences and the understanding of cities as urban ecosystems. Young students realize their potential to actively participate and contribute to science. Based upon the own experience of active participation, the students learn how science works and built the self-confidence of being able to become a scientist, even if this notion is not the norm in the own social stratum.

In the 6th month of the implementation of the PULCHRA project, the vast majority of partner countries-imposed restriction measures – also with respect to schools' operation and activities – due to the pandemic. PULCHRA had to readjust its work program, adjust its activities (Workshops, open meetings with the stakeholders, etc.) to virtual meetings and events and develop contingency plans in close collaboration with the European Commission.

At present, all partners have deployed their activities, the project has been media launched at the European and national levels, the educational material has been developed, and most importantly a network of 52 schools has been developed. The signs as to the potential of the project are positive, yet the assessment on the compliance of the project to its objectives is to be done at the conclusion of its 2nd year of operation. Valuable conclusions have resulted in terms of the capacity of students to undertake science challenges linked to the urban environment, the importance of open schooling and the potential of schools to adapt to unpredicted situations such as the pandemic while at the same time promote the project.

An obvious finding of the PULCHRA project is the potential of open schooling for science education. Despite the varying educational systems of the member States which participate in the project, it was possible to develop common grounds for science education and develop a solid network able to exchange best practices and cooperate towards innovation (EC, 2019).

In addition, the architecture of the project namely to form Science Teams in the schools, to develop City Challenges in six themes, to activate the Science Reporters for the communication of the project to the local communities and the stakeholders and to develop the City Challenges Platform as the "meeting point" of all school projects as well as of the stakeholders with the schools has been proven successful.

Corrective measures need to be applied so as the project to take note of the variations in the educational systems of European countries as far as open schooling is concerned, as well as to comply with the overloaded school programs. Furthermore, the project needs to organize its replication model in view of its expansion to other schools and/or countries.

CONCLUSIONS AND OPEN ISSUES

The four presented projects showcased four complex different point of departures, pathways and approaches in which each project address the gap between science and society and how each of them positioned for making science education more responsive to changes in society.

Despite the profound differences, the projects still presented many synergies, like the idea of co-developing scientific knowledge together with different stakeholders as well as placing the learning process within a democratic dialogue, capable of fostering transformative engagement. In this sense, the presentation of the four point out not only the need of a multidimensional interaction among different stakeholders but also toward a strong re-definition of perspectives. Beyond these needs, all the projects highlighted, from their particular perspectives, that we really need to focus on beginning to closely assess opportunities for improving schools and the education system; we need open-mindedness, social responsibility and a collective power for imagining and designing spaces to stimulate the intelligence and curiosity of girls and boys within the context of school science.

Open schooling offers unequalled opportunities for looking for boundary crossing opportunities (inside, outside, inside-out, outside-in) and triggering deep cultural transformation in bridging school science and society.

To what extent we can dive into transformation? We wish to conclude by taking into serious account a provocative suggestion made by the discussant of this symposium "*Daring to be disruptive, to go against what is expected or considered 'normal' – toward transition pathways*".

ACKNOWLEGMENTS

The symposium was chaired and organised by Giulia Tasquier and Erik Knain. All the contributors are deeply grateful to the discussant, Arjen Wals, who helped in stimulating rich reflections for the symposium. Results coming from each of the projects is an inside-out and outside-in collective process of mutual feeding created by each consortium. The authors of this paper would thank all the partners of each of the projects for the collective endeavour in pursuing projects' goals and contributing to their achievements.

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ON THE WAY TO EVIDENCE-BASED REASONING OF SOCIOSCIENTIFIC ISSUES
IN SCIENCE TEACHER EDUCATION

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A central implication of scientific literacy is the ability of students to participate in discourses and decision-making processes concerning societal challenges, such as climate change, on basis of their acquired scientific knowledge. In order to provide them with the corresponding competences it is necessary that teachers themselves are enabled to participate in matters of social importance and this entails acquiring corresponding subject-matter knowledge as well as the ability to evaluate varies sources of data and information. The topic 'limit values of pollutants in the air and their implications' is one possibility to focus on subject-matter knowledge for the development of social challenges. A preliminary study has revealed that preservice chemistry teachers not only lack appropriate knowledge but furthermore have difficulties in dealing with data and information sources to assess societal challenges raised by pollutants in the air. To address these deficiencies a course was designed which aims at knowledge acquisition and possibilities to put this into practice. Within the framework of knowledge acquisition, students were instructed in subject-matter knowledge and limit value knowledge as well as how to deal with data and information sources.

A piloted open questionnaire in a pre-post design and reflection questions were used to assess the outcome of the course. Fifteen preservice chemistry teachers took part in this study, which was carried out as an online course due to the pandemic. The results show that the deficiencies of the necessary content knowledge as well as the handling of data and information sources could be reduced. In a next step, the results will be validated with problem centred interviews and with regard to the dimension of action orientation preservice chemistry teachers' abilities to transform the societal challenges and their implications into teaching practice will be considered.

Keywords: Initial Teacher Education (Pre service), Scientific Literacy, Socioscientific Issues

INTRODUCTION

The Smart Chemistry Teachers Cologne (SChemTeC) project, which was funded by the City of Cologne as part of SmartCity Cologne GO, aimed to guide preservice chemistry teachers to acquire subject-specific knowledge about sustainable, responsible and smart design of the city of Cologne and to transform it into teaching practice. A smart city needs people who are able to shape their living space in a well-founded way, but who are also capable of developing new approaches in such a sustainable way that city life, the environment and the quality of life of present and future generations are preserved and even improved (Möhlendick & Kreitsch, 2018).

CONTRIBUTION OF SCIENTIFIC LITERACY TO PARTICIPATION

One of the central aims of science education is to provide students with a scientific literacy that enables to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity, and to participate in making decisions in this regard (OECD, 1999, p. 60; OECD, 2017,

p. 20). Some of these changes made to the natural world by human activities lead to societal challenges (Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland, 2020, p. 11; National Research Council, 2012, p. 212; National Research Council, 2013, p. 109), such as anthropogenic climate change or air pollution. This is because air, as a mixture of atmospheric gases, surrounds the entire earth, and consequently moves across national boundaries, and air pollution therefore affects people and environment globally. In terms of climate change and mitigation of its consequences, compliance with established limit values, such as those from the Paris Climate Agreement (Vereinte Nationen, 2016), is of particular importance. Due to their consequences for human health, the social debate about limit values of nitrogen oxides, which has led to controversial discussions (Menthe & Hüffner, 2019; Nationale Akademie der Wissenschaften Leopoldina, 2019), is similarly well-known.

In science it is up to the teachers to promote scientific literacy and they themselves must become scientific literates who are able to participate in socially relevant discourses (Zeidler, 2014). The idea of scientific literacy implies as a necessary condition presupposing that both a solid content knowledge of problem analysis (Höttecke & Allchin, 2020, p. 643) and competences to evaluate different sources of data and information in order to make fact-based decisions and to deal with evidence adequately (Archila, Molina, Danies, de Mejia & Restrepo, 2021; Sharon & Baram-Tsabari, 2020).

Consequently, skills for applying the acquired chemical expertise and knowledge about limit values must be given in order to recognize scientific questions from the living world and to be able to draw conclusions with the help of various data and information sources. In addition, the ability to transform the corresponding problem into teaching practice must be given as a sufficient condition. Although the project addresses both conditions, the following contribution is limited to the necessary condition.

THEMATIZATION OF RISKS USING THE EXAMPLE OF LIMIT VALUES

The challenges associated with emissions of the oxides of carbon and nitrogen pose ubiquitous risks to humans, animals and the environment (Pietrocola, Rodrigues, Bercot & Schnorr, 2021, p. 3). According to Beck's thesis of risk society (Beck, 2016, p. 26), these are caused by humans and are associated with new technologies and products. In dealing with these risks, (natural) scientific knowledge has a special significance, because for the most part these risks cannot be perceived through the sensory organs but become visible and interpretable by means of the instruments of science (experiments, models, theories) (Beck, 2016, p. 35). Therefore, in order to participate in appropriate decision-making processes, people, most of whom are scientific laypersons, must have confidence in science, be able to comprehend scientific findings and be able to evaluate certain risks (Pietrocola, Rodrigues, Bercot & Schnorr, 2021, p. 21; Hansen & Hammann, 2017, p. 749).

One way to address these risks is through limit values, which are often used in health and environmental policy (Bächi, 2012; Böhm, 2012; Dieter, 2009; Wicenec, 2000). Compliance with limit values is monitored institutionally and in a standardized manner and sanctions are imposed if they are exceeded, so that they have a regulating function, i.e., a limiting function, as well as an informing function about potential hazards and about sanctions in the case of exceedance (Bächi, 2012, p. 119; Wicenec, 2000, p. 2). Limit values are set by politicians in an interdisciplinary and staged process of consideration and are passed in the form of legal texts whereby a field of tension, e.g., between natural sciences, law and politics, arises (Böhm, 2012, p. 59; Wiedemann, 1998). Corresponding discourses about limit values can be considered as Socioscientific Issues because according to Hancock, Friedrichsen, Kinslow and Sadler (2019) – they fulfill the following characteristics: they are "current, controversial, relevant to students, have connections to science content, and allow for open discussion among learners" (Hancock, Friedrichsen, Kinslow, & Sadler, 2019, p. 643). In order to grasp the complex concept of limit value in a more purposeful way and to make it fruitful for this study, the following working definition was formulated:

Limit values are measures in the form of fixed pollution limits that are intended to protect the life-support systems of soil, water and air for humans, animals and plants from substances that affect them, that harm them and that endanger their existence, with the aim of preserving and safeguarding them, as well as reducing the corresponding risks.

In chemistry teacher training, discourses about limit values and their implications can be used in the sense of the principle of exemplariness to create the above-mentioned prerequisites for participation in societal challenges.

RESEARCH QUESTION OF THE STUDY AND STRUCTURE OF THE COURSE SCHEMTEC

Within the framework of a preliminary study, questionnaires had revealed that prospective chemistry teachers on the one hand do not have the necessary content knowledge to adequately understand and problematize social challenges associated with the oxides of carbon and nitrogen as pollutants in the air. And on the other hand, they are uncertain in dealing with data and information sources. These deficiencies were the starting point for the conception of this project and led to the following research question: To what extent can the designed course SChemTeC reduce the deficiencies of preservice chemistry teachers with regard to the prerequisites for participation in discourses about societal challenges of pollutants in the air? Within the dimension of knowledge acquisition, not only the necessary technical basics of pollutants in air were taught on the basis of the oxides of carbon and nitrogen, but also different implications and positions within the corresponding discourses. They were instructed to use and reflect on a wide variety of data and information sources in order to reduce uncertainties.

Thematically, knowledge acquisition started with reading and discussing of media reports, followed by a presentation and discussion of projects in Cologne, such as the climate road or e-buses of the Cologne public transport company. Furthermore, the participants discussed consequences of the so-called "Cologne Lights", a music and firework event near the Rhine, and possible alternatives. Based on this context-based introduction, factual analyses on the topic of climate change and air pollution were prepared in groups dealing with formation, release, mode of action and consequences of the oxides of carbon and nitrogen.

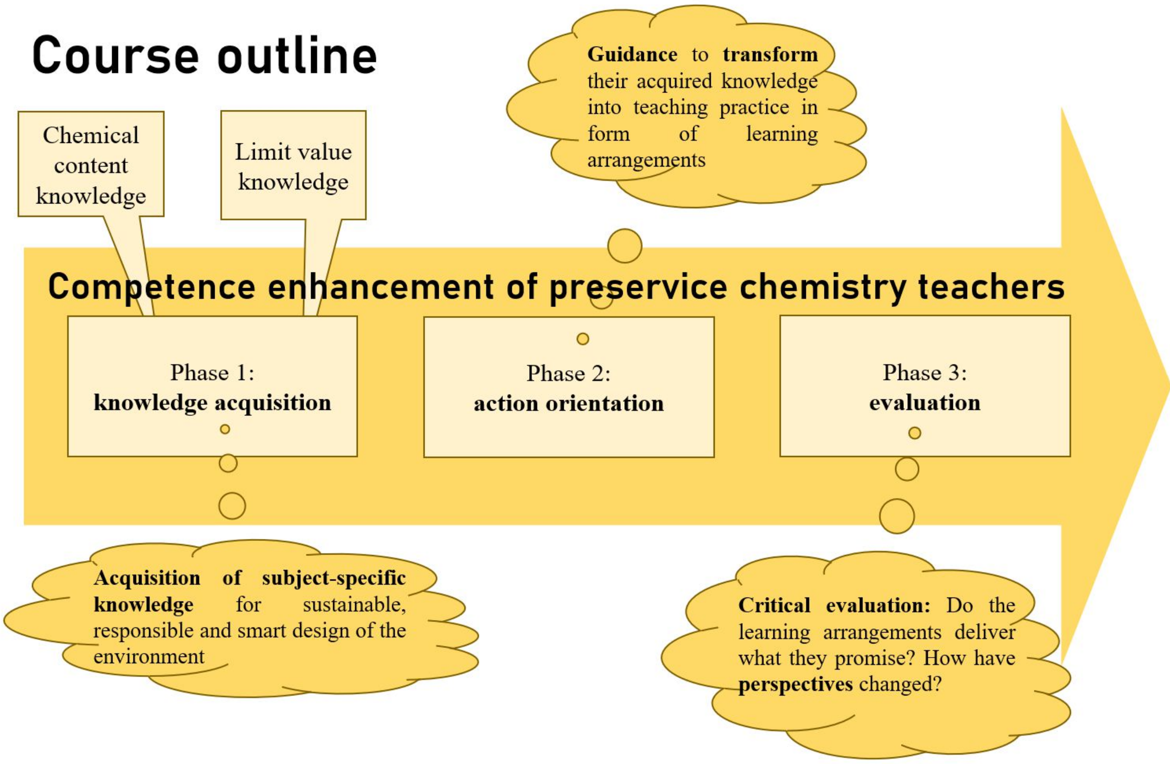

Figure 18. Course outline of SChemTeC.

These factual analyses were optimized based on feedback from the students during their presentations. They first dealt theoretically with the concept of limit values and then explored the city of Cologne with the intention of finding out place (where?), content (what?) and methods (how?) of the measurement. In the course, various methods for determining air quality were reflected together. The knowledge acquisition phase concluded with a guiding question-based reflection. This was followed by the phases of action orientation, in which the preservice chemistry teachers were guided to transform their acquired knowledge into learning arrangements, and evaluation, in which they reflected on these arrangements.

RESEARCH METHODOLOGY

Fifteen preservice chemistry teachers from all types of schools at the beginning of their Master program or at the end of their Bachelor program participated in the study; due to the pandemic, these courses took place online and run eleven weeks with four hours per week. For the survey, different instruments were used in a between-methods triangulation (Flick, 2018). An open-ended questionnaire in a pre-post design elicited the students' chemical expertise as well as their knowledge of limit values in general and that of the limit values of the so-called pollutants in the air. The questionnaire was piloted as part of the preliminary study and developed accordingly. For further data collection, preservice chemistry teachers documented in reflection tasks their further developments and the challenges they saw regarding the handling of data and information sources. At the end of the course, problem-centered interviews (Witzel & Reiter, 2012) (n = 2) were used to elicit reasoned positioning, to collect further data, and to validate existing findings. All data obtained were analyzed using Mayring's Qualitative Content Analysis (Mayring, 2015). The questionnaires were evaluated deductively using a category system developed on a literature-based factual analysis, while the interviews and the reflection tasks were evaluated inductively. The deductively developed category system is divided into the main categories "chemical content knowledge" and "limit value knowledge".

RESULTS OF THE QUESTIONNAIRES

Table 1 shows the codings of the first three questions of the questionnaire related to the level of expertise. The first question was about the characteristic properties of the oxides of carbon and nitrogen, the second question was about formation and emission sources, and the third question was about the consequences for humans, animals and the environment. From each of these, the three categories below were derived as the main categories, which can be further differentiated. Table 1 shows that an overall improvement can be observed in chemical content knowledge on the oxides of carbon and nitrogen: while in the pre-questionnaires a total of 78 codings are detectable, 113 codings can already be set in the post-questionnaires.

Table 29. Codings of chemical content knowledge in the questionnaires.

Deductively formed categories of chemical content knowledge	Pre-questionnaire	Post-questionnaire
Characteristic properties of carbon and nitrogen oxides	58	56
Formation and emission source of carbon and nitrogen oxides	13	37
Consequences of carbon and nitrogen oxides' emissions	7	20
Codings of chemical content knowledge overall	**78**	**113**

The fact that the amount of characteristic properties of carbon and nitrogen oxides is minimally declining can be explained by the fact that two questionnaires were incomplete. The results reveal that from the beginning, the chemistry students have significantly more expert knowledge with regard to the characteristic properties than with regard to formation, emission sources and consequences. In the last two categories, there is a clear increase from the pre- to the post-questionnaires over the course. It is striking, for example, that one person answered the question about the consequences of the oxides of carbon in the pre-questionnaire on the one hand superficially with the term *"greenhouse effect"* (ABS234A, PrF) [all translations by the authors] and, on the other hand, answered more substantially in the post-questionnaire: "*First, there are some effects on the climate, or functions in the atmosphere, namely absorption and reflection of thermal radiation. When there is too much CO_2 in the air, more thermal radiation is reflected back to earth, which has a warming effect*" (ABS234A, PoF).

Table 2 shows the codings for the limit knowledge that was collected in the questionnaires via questions four and five. The fourth open-ended question addressed meanings of limit values on the oxides of carbon and nitrogen: "*What do the limit values of the oxides of carbon and nitrogen, which are discussed in the media, mean or say?*". The fifth open question is: *"Describe possible problems, challenges as well as insights associated with the limit value discussion about the oxides of carbon and nitrogen"*. Since these two questions thematically survey limit value knowledge, five main categories were deductively formed, which are reflected in Table 2.

Table 30. Codings of limit value knowledge in the questionnaires.

Deductively formed categories of limit value knowledge	Pre-questionnaire	Post-questionnaire
Intentions, expressiveness and specific values of limit values of carbon and nitrogen oxides	5	6
Monitoring compliance with the limit values for carbon and nitrogen oxides	1	5
Process of setting limit values for carbon and nitrogen oxides	0	12
Social discourses on limit values of carbon and nitrogen oxides and their implications	3	10
Communication of limit values for carbon and nitrogen oxides taking uncertainties into account	0	3
Codings of limit value knowledge overall	**9**	**36**

With regard to limit value knowledge, they improved from nine codings in the pre-questionnaires to the 36 codings in post-questionnaires. Especially in the category on the processes for setting limit values for carbon and nitrogen oxides, there are no longer zero codings in the post-questionnaires, but twelve codings. The course also enabled preservice chemistry teachers to deepen their knowledge of social discourses on limit values for carbon and nitrogen oxides and their implications, as the codings enhanced from three in the pre-questionnaires to ten codings in the post-questionnaires. While in the pre-questionnaires the students often noted statements with regard to the discourse of limit values for pollutants in the air, such as *"however, these values are often arbitrarily set (e.g., by the EU) and rarely scientifically proven"* (ÖLF569F, PrF), a clear improvement in the technical depth and differentiation could be noted in the post-questionnaires. This is evidenced by statements with regard to the negotiation processes underlying limit settings, such as: *"It is an interplay between health/conservation and economic/political interests"* (PWÜ528Q, PoF)

RESULTS OF THE REFLECTION EXERCISES

In order to document their development preservice chemistry teachers were asked to write a reflective assessment. To assist them, they were provided with a list of assessment prompts that address, for example, knowledge enhancement, challenges, and insights in the context of the course. The importance of the initiating impulses can be exemplified by the challenges of researching adequate information and sources. The following quotation illustrates that due to the abundance of information, a reasoned selection must take place. Therefore, competencies are needed to assess reliability of information*: "When I looked on the Internet, I also found that there was an abundance of material that one often couldn't be sure of whether it was reputable or not"* (ASD869S, RW). Therefore, especially for scientific laypersons, there is a need for teaching competencies in dealing with data and information sources. It also turned out that reliable sources are often not accessible without barriers. Sometimes access on the Internet is subject to a fee. Especially the research of suitable sources on the Internet via search engine, which is also the preferred access for most citizens, is challenging: *"Finding suitable sources has always been a clear challenge. Many sources are either not scientifically reliable or protected by various paywalls"* (SDC556H, RW).

In the reflection exercises, 40 % of the participants describe the critical examination and assessment of information, sources, and media as a central further development, which is also confirmed by the two interviews. In the reflection tasks, around 67% of the participants named researching adequate information and sources as a particular challenge. With regard to the further development of preservice chemistry teachers, it was inductively deduced as a category that competencies for critical examination and assessment of information, sources and media represent a central further development. On the one hand, students were encouraged to be critical of statements from the media in such a way that every statement must pass a content-based test: *"I was encouraged to deal more with these realistic, every day and important topics in detail and also to critically question every statement. From measurement procedures to established limit values"* (UDG631Z, RW). On the other hand, in addition to classical media, many of the students also refer to (explanatory) videos to gain knowledge, so that they could now have the insight that these videos cannot be regarded as error-free from the outset, which makes an important contribution to dealing with social media in general: *"Be more sensitive with YouTube videos, which can have errors and cause misconceptions with students"* (GGT887T, RW).

RESULTS OF THE INTERVIEWS

At the beginning of the course, preservice chemistry teachers mostly assumed that the applicable limit values are set by science. The following quotation shows that the student reflects successfully on the process of setting limit values: *"What is exciting somehow is (...), someone must have said yes: yes, from this limit value, from here it becomes harmful. And then, above all, it is ultimately a decision that actually initiates actions, somehow in the political context and they have to be made by experts and they come mainly from the health sector and the scientific sector somehow"* (AQY987G, I). This quotation illustrates that an understanding of limit value setting requires the competence to reflect on it as a discursive process in order to adequately participate in corresponding social discourses.

Furthermore, the interviews show that competencies in handling data and information sources critically could be acquired. The following statement proves that checking the author can be a first step when there are uncertainties about the credibility and validity of the source: *"That you just look carefully, if necessary, look at the author: Does he have any particular CV? Where* *did he graduate if he graduated at all?"* (WER861V, I). This was coded inductively as part of the challenge to research adequate information and sources.

The following passage illustrates that a critical attitude towards statements made in the media is transferred to everyday life: "*Yes. In any case, I notice that the very fact that you have dealt with such a topic, be it air pollutants or anything else, like climate or environment, once you have dealt with it and you encounter it again, be it in the media or anywhere else, (.) that the first reaction is not: >>* ***Oh, yes, that's the way it is.*** *<<, but: >>**Aha, is that so?** <<"* (AQY987G, I). Here, a conceptual change initiated by the course becomes obvious.

DISCUSSION OF THE RESULTS AND CONCLUSIONS

The results of the questionnaires show that the acquisition chemical knowledge and limit value knowledge was successful, so that preservice chemistry teachers could improve. With regard to the results of the reflection tasks and interviews, it can be stated that first steps were taken to reduce uncertainties in dealing with data and information sources. In follow-up studies, more attention should be paid to knowledge about science communication and the handling of evidence. The interviews revealed that the perspective for dealing with discourses about societal challenges has changed.

However, it is also apparent that the contextualized limit value knowledge can still be extended. Therefore, concept maps are to be designed for networking during the knowledge acquisition phase. In addition, the number of participants has to be increased and further topics (such as microplastics or nitrate pollution) have to be developed.

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CRITICAL THINKING IN SCIENCE - TEACHERS' PERSPECTIVES

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Critical thinking is considered to be a key to mastering current and future global, ecological and social challenges. However, the understanding of the concept of critical thinking in the literature is manifold and partly different. We are guided by Dewey, for whom thinking and acting form a coherent unit. In the context of school, action should be oriented towards the goals of education, so that critical thinking in science teaching cannot be implemented in isolation from contexts, norms and values. From this we have derived the question, which perspectives on critical thinking exist among (science) teachers? These perspectives could be helpful clues for the development of school and teaching approaches that focus on critical thinking as well as in the context of Socio-Scientific Issues (SSI) in science education. For this purpose, an exploratory questionnaire study was conducted among teachers, with open and closed questions, which also indicates a diverse understanding of concepts among teachers. There are also indications of differences with regard to specifically science subjects and e.g., mathematics, which can be expected to provide detailed findings in the context of a validated main study. The teachers were also asked to assess themselves and their students with regard to the practice of critical thinking in class. Here, a discrepancy seems to emerge between the perceived lack of critical thinking on the part of the students and too few situations where they are actually allowed to think critically.

Keywords: Critical Thinking, Scientific Literacy, Teachers' Perspectives

THEORETICAL BACKGROUND

Critical thinking is an important approach to social, economic, and environmental problem solving and decision making (Rychen, 2008). In particular, critical thinking is said to help students understand and grasp complex contexts (Staudinger, 2019; Bourn, 2018). In the German school context, critical thinking makes up an important skill in the context of education for sustainable development (MSB NRW, 2019; Grundmann 2017, Riekmann, 2016) as well as in the subject of philosophy, where critical thinking is originally an integral part (Künzle, 2016; Pfister 2020). Furthermore, in German-speaking countries there are hardly any approaches to embed critical thinking in school (Petri, 2003; Rosa, 2017; Rafolt, Kapelari & Kremer, 2018, 2019; Drerup, 2021), in contrast to countries with a curricular connection to critical thinking and a scientific discourse about critical thinking in school (Ennis, 2016; Nygren, Haglund, Samuelsson, Af Geijerstam & Prytz, 2019, Abrami et al., 2015, Balin, 2002; Sternberg, 2020). Embedding critical thinking in science education seems on the one hand obvious in the context of ESD. On the other hand, the broader question arises to what extent critical thinking could be an aspect of science education that not only focuses on intellectual skills and knowledge, but also includes the ethical dimension of scientific issues in a societal context related to socio-scientific issues (SSI) (Nerdel, 2017, Dittmer, Gebhard, Höttecke & Menthe, 2016). A major problem is the conceptual understanding of critical thinking, which can vary widely or is not explained at all in this context.

While there are approaches such as critical thinking skills that are more in line with a cognitive psychology perspective, these are not necessarily congruent with a philosophy of education perspective. Rafolt et al. (2019) have developed a synergy model for critical thinking in science education, in which certain characteristics and criteria guide the process of critical thinking. They address aspects of critical thinking skills and consider areas such as norms and values, attitude, and motivation among others. Moreover, there seems to be sufficient reference to subject teaching of critical thinking in science education so far (Sternberg, 2020).

In our approach, we assume that a school concept of critical thinking is to be constituted from across different subjects, from which a subject-specific conceptualization is to be derived, and that science education must also contribute to education. In this regard, we refer to Dewey, who emphasizes: "No one doubts theoretically the importance of fostering good habits of thought in school." (Dewey, 1916, p.179). Furthermore, Dewey does not view thinking and acting from a dualistic perspective: “Thinking [...] is the intentional endeavor to discover specific connections between something which we do and the consequences which result, so that the two become continuous” (Dewey, 1916, p. 170). Going further, for Dewey, thought and action must be successful. What successful action can mean, however, requires concretisation. In the context of socio-scientific issues, reference could be made here to norms and values, such as those formulated in the SDGs (Hasslöf & Malmberg, 2015). Yet, critical thinking is not only passively influenced by norms, values or personality traits, but also has an effect on them through action. That is, critical thinking can also lead to a change or renegotiation of norms and values. And at the same time this interaction can contribute to personality formation.

For science teaching and school practice in general, this raises the question of how situations for critical thinking and the corresponding interactions can be facilitated and promoted. The basic requirement for these situations is that critical thinking must be able to develop tangible relevance. The space for action must therefore not remain abstract or hypothetical. School practice is primarily planned by teachers, but teachers' ideas about critical thinking and the provision for critical thinking in the classroom are unknown (Rafolt et al., 2019). This finding is the starting point of this study, which addresses the following research questions:

- What are teachers' perceptions of critical thinking and its importance for schools?
- To what extent is critical thinking currently an issue in school and classroom practice?
- How do teachers assess their learning groups in terms of attributes relevant to critical thinking, such as attentiveness, reflectiveness or the pursuit of knowledge?
- Are there subject-specific perspectives on critical thinking, e.g., in science?

METHODS

A self-developed, online-based questionnaire was used to examine teachers in an exploratory study. The target group of the exploratory study was teachers of german secondary education [N=50]. The questionnaire contains both open and closed response formats.

The questionnaire includes questions about teachers' perceptions of critical thinking (10 items) and teachers' perceptions of their student body (11 items). The questions on critical thinking include aspects such as understanding and defining critical thinking, characteristics of a critical thinker and classroom references. Teachers' assessments of their students refer to personality traits or classroom behaviours, such as attentiveness, reflectiveness, or thirst for knowledge. Response options were scaled as a rating scale (Döring & Bortz, 2016) according to the estimated proportion in the learning groups (all, many [more likely the majority], about half, fewer [more likely the minority], none, not specified).

The open-ended response formats were interpreted using qualitative content analysis (Mayring, 2010), while the closed questions were analysed descriptively or exploratively using factor analysis with SPSS.

RESULTS

In this small sample, 50 teachers of german secondary education participated. Of these, 40.8% were male and 57.1% were female. The teachers had an average seniority of 14.7yrs. (SD 12yrs). Science subjects were reported as 12% biology, 10% chemistry and 12% physics. The first results of the explorative study show that all teachers, irrespective of subject, believe that critical thinking is an important teaching goal. However, there are clear differences in their understanding of critical thinking, both across all subjects, but also among the science teachers. The content-analytical evaluation of the question on the definition of critical thinking shows from the teachers' point of view that questioning (52%) constitutes the essential aspect for critical thinking. Judging (32%), reflecting (28%) and forming opinions (24%) are also important. Critical thinking was defined as a skill in 10% of the statements, while the term competence did not appear at all. In contrast to the open-ended response option in the definition of critical thinking, responses to the question *What knowledge, skills and dispositions must a critical thinker have?* show that self-reflection, judgement, evaluation of skills, ambiguity tolerance and analytical thinking skills are important characteristics for critical thinking. Empathy is also an important factor from the teachers' point of view. Figure 1 shows the aspects that teachers consider important for critical thinking.

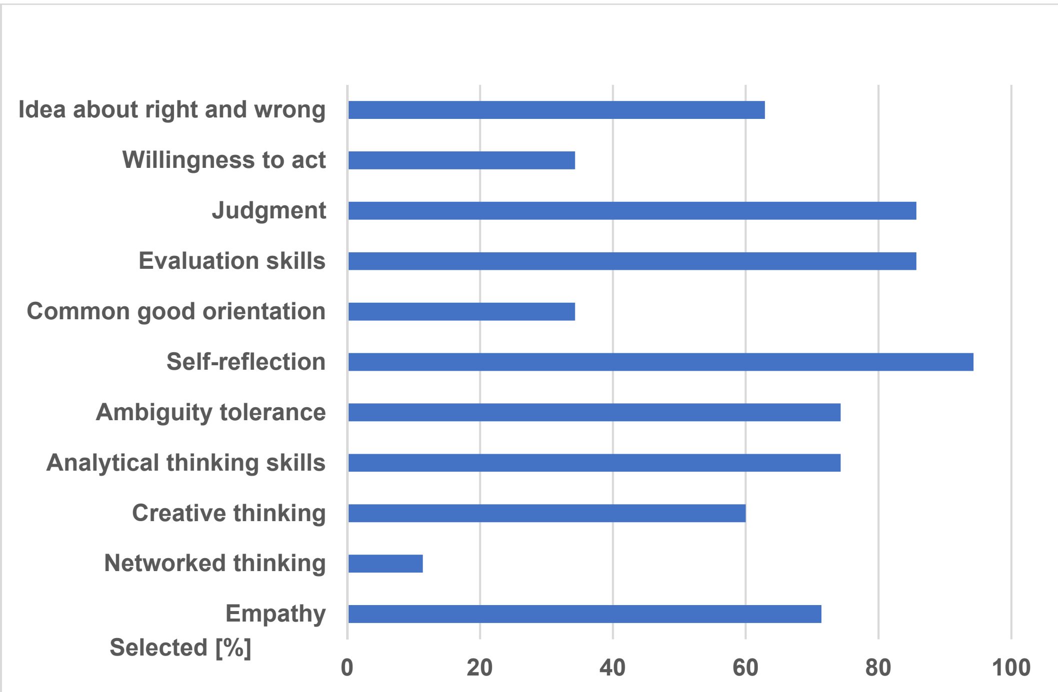

Figure 1. What knowledge, skills and dispositions must a critical thinker have?

In contrast to the definitions given about teachers' critical thinking, the ability to self-reflect is most frequently mentioned here. Empathy is also highlighted. This picture largely coincides with the definitions of the APA.

In our survey, we were also interested in the extent to which teachers assessed students' abilities in the context of critical thinking within their classes. To this end, we asked teachers what proportion of students in their class they would rate to have following skills, e.g., "How many of your students are ready to think independently about complex questions and issues?" The response options here were none (=1), less than half (=2), about half (=3), more than half (=4), or all (=5). Here we found that, on average, the teachers estimated that about half of their students

- engage with open-ended questions and problems (M = 2.86, SD 0.73)
- are able to independently seek out reliable information on a new and complex topic. (M 3.34, SD 0.73)
- are able to reflect on their own thinking (M 3.43, SD 0.74)
- are able to recognize experts in a topic area as such (M 3.0, SD 8.4)
- are able to reflect on their own learning (M 3.06, SD 0.80)
- are willing to think independently about complex questions and issues (M 3.11, SD 0.68)

On average, teachers estimate that many (rather the majority) of the students stand out as attentive (M 2.34, SD 0.54).

An exploratory factor analysis showed that the relationship of students towards critical thinking allows for two subscales, which can be characterized once as Independent Reflection (3 items, Cronbach's α= 0.72) and Willingness to Think (3 items, Cronbach's α= 0.62). We hope that this picture will be consolidated in the next survey.

When it comes to the question of where critical thinking is integrated into subject lessons, the focus is on environmental, climate- or ecological topics. About 20% of the answers (free response format) had their focus here. The following excerpts exemplify some responses:

"Critical thinking can be tied to observed phenomena from a biological perspective: "Why are honeybees dying?", "Why are there so many bark beetles?" These questions lead directly to changes in ecosystems, which are also linked to climate change. Students must therefore inevitably ask themselves what contribution each individual can make to changing the problem." "Genetic engineering, vaccination, cell culture technology (ethical discussion), sustainability and environmental protection (biodegradable plastic versus conventional plastic)." "In combination with classroom topics, e.g., climate change in physics and its effects (panel discussion, etc.)"

The teachers were also asked to indicate in which subjects critical thinking can be particularly well stimulated. Here we observed that the main subjects Mathematics, German and English were mentioned comparatively little (12-14% each), while social science subjects such as Religion (42%), Philosophy (54%), History (44%) and Social Sciences (44%) are frequently named. The science subjects are also named less frequently, contrary to the topics mentioned (see above): Biology (20%), Chemistry (18%) and Physics (14%).

DISCUSSION

The results of the exploratory study show that all teachers, regardless of subject, consider critical thinking to be an important instructional goal. However, there are significant differences in the understanding of critical thinking, both across subjects and among science teachers. For example, when asked what qualities are relevant to critical thinking, there is undisputed agreement only on self-reflection and networked thinking.

However, it also becomes clear that teachers on the one hand advocate for critical thinking skills. On the other hand, their understanding of critical thinking seems to go beyond these skills, especially in the aspect of empathy. This raises the question of how empathy skills could be taught in science classes.

When assessing students, it appears that teachers only attribute important qualities, such as the ability to self-reflect or the willingness to engage with complex issues, to half of their students. Together with the teacher's feedback that, from their point of view, there are only few opportunities in the subject lessons for critical thinking, it also seems to emerge here that the subject lessons hardly promote critical thinking. On the question of where critical thinking is integrated into subject lessons, the focus is clearly on environmental or ecological topics, as the following excerpts exemplify: "Critical thinking can be hung on observed phenomena from a biological perspective: "Why are honeybees dying?" "Why are there so many bark beetles?" These questions lead directly to changes in ecosystems." It seems obvious that these topics are likely to promote critical thinking. However, it should be noted that a topic alone does not necessarily stimulate critical thinking. It depends on how deeply the connections to social issues are considered and what opportunities are provided for students to make critical thinking relevant.

In summary, science education should integrate critical thinking explicitly and implicitly as an important educational goal. In this context, subject-specific scientific knowledge is an important prerequisite for critical reflection in the context of social science issues. Here, interdisciplinary networking between subjects or teachers is probably necessary in order to be able to draw on non-scientific expertise.

More historical, biographical or societal contexts as well as case studies related to science are needed to provide suitable teaching occasions for critical thinking (e.g., Schaake, 2011; Henke & Höttecke, 2011, Wilhelm, Rehm & Reinhard, 2011). This is also associated with more teaching opportunities in which students feel more engaged emotionally by problems, so that critical thinking can be practiced and internalized situationally.

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EMOTIONS ABOUT SOCIOSCIENTIFIC ISSUES TO DEVELOP CRITICAL THINKING IN SPANISH PRE-SERVICE SCIENCE TEACHERS

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Nowadays, science education should focus on the development of competences in students, and especially on the development of different skills that allow them to work out their critical thinking without forgetting the emotional aspects of students that can significantly influence the teaching-learning process. Argumentation and decision making are considered important skills to foster critical thinking and can be developed through socio-scientific issues in the classroom. A training programme for pre-service science teachers (PST) on critical thinking was developed based on these ideas, focusing on socio-scientific issues in different formats (text, video and opinions). This programme was implemented with 43 Spanish PSTs from the Master in Secondary Education at the University of Málaga (Málaga, Spain) during the academic course 2019-2020. The first phase analysed the emotions felt by the PSTs during the implementation of different issues included in the programme focused on energy, health, or technology. For data collection, the PSTs completed a questionnaire, including a list of emotions. The data were analysed qualitatively, comparing positive and negative emotions. It was found that, regardless of the dilemma format used, the emotions felt by the PSTs were positive, with particular emphasis on their interest and attentiveness. Insecurity appeared in the short opinions´ format to solve the dilemma as a main negative emotion. These results show that the use of socio-scientific issues in different formats can be very suitable for developing critical thinking since the emotions detected favour learning.

Keywords: Emotion, socio-scientific issues, critical thinking

INTRODUCTION

In recent years, there has been growing concern about students' declining interest in science learning, among other reasons, because it focused on the transmission of knowledge based on conceptual change and without considering the emotional side (Mellado et al., 2014). An understanding of the role of emotions in science education, and the ability to reflect on them, implies an understanding of the nature of the cognitive processes involved (Franco-Mariscal, Cebrián & Rodríguez, 2021). Different studies in science education provide evidence that positive emotions and enjoyment from learning science play a significant role in learning outcomes and serve as a driving force for self-learning, and for retaining knowledge (Nicolaou Evagorou & Lymbouridou, 2015). It is necessary to train competent teachers with critical thinking who know how to diagnose and self-regulate their emotions both in the cognitive and affective areas.

In science education, critical thinking includes as fundamental aspects criticism and questioning in the practice of science since it seems impossible to think that without arguments and their evaluation it would be impossible to build reliable knowledge (Osborne, 2014). According to Vázquez and Manassero (2018, 2020), creativity, reasoning, argumentation, and complex processes are critical thinking's outstanding skills, both in the cognitive and attitudinal fields. In short, science education faces the challenge of forming competent citizens who incorporate argumentation, criticism and decision making into their daily lives and, at the same time, self-regulating their emotions as they can act as facilitators or obstacles to teaching-learning.

Although the literature includes different teaching strategies to develop critical thinking, there is no clear identification of a valid methodology for the classroom. An overall strategy is the use of educational issues or situations posed through socio-scientific problems (Evagorou, Jiménez-Aleixandre & Osborne, 2012), in which the student must decide reasonably between apparently incompatible options (Franco-Mariscal, Hierrezuelo-Osorio, Cruz & Cebrián, 2021) and where they also work on important skills such as argumentation and decision making (Fang, Hsu & Lin, 2019).

This work presents the results of the emotions felt by Spanish pre-service science teachers who participated in a training programme on critical thinking focused on the development of argumentation and decision making as important skills in science education and using socio-scientific issues as a teaching strategy.

METHOD

Participants

This study was performed with 43 pre-service science teachers of the Master in Secondary Education of the University of Málaga (Málaga, Spain). The 56.3% were women and 43.7% men, aged between 21 and 51 years. The pre-service science teachers studied innovation and educational research in Physics and Chemistry (N=16) and Biology and Geology (N=27) specialities during the academic year 2019-2020.

Instruction

The pre-service science teachers participated in a programme with eight sessions of 90-minute in which argumentation and decision making were addressed as critical thinking skills (Sadler, & Zeidler, 2005; Jimenez-Aleixandre, 2010) and different socio-scientific issues related to energy, health and technology were analysed (Hierrezuelo-Osorio, Franco-Mariscal & Blanco, 2022). The programme was developed in the following four phases (see figure 1):

- Phase 1. Initial assessment of pre-service science teachers' argumentation and decision-making skills as important critical thinking skills and their perception about them (1 session) (pre-test). In this session, several activities focused on socio-scientific issues in different formats and a questionnaire about critical thinking (CPC2) (Santiuste et al., 2001) were used as a pre-test.
- Phase 2. Instruction with pre-service science teachers (4 sessions). This phase addressed different models of argumentation and critical thinking, analysis of an issue, and preparation and staging of a role-play.
- Phase 3. Application of knowledge (2 sessions). Pre-service science teachers, in the role of teachers, designed a group activity to develop critical thinking skills with students at their level of education and presented them to their peers.
- Phase 4. Evaluation of critical thinking skills and perception of the pre-service science teachers after the programme (post-test) (1 session) was assessed with different

instruments. A questionnaire about emotions (KPSI) (Martínez, Jiménez-Liso & Evagorou, 2019) was administered in this phase.

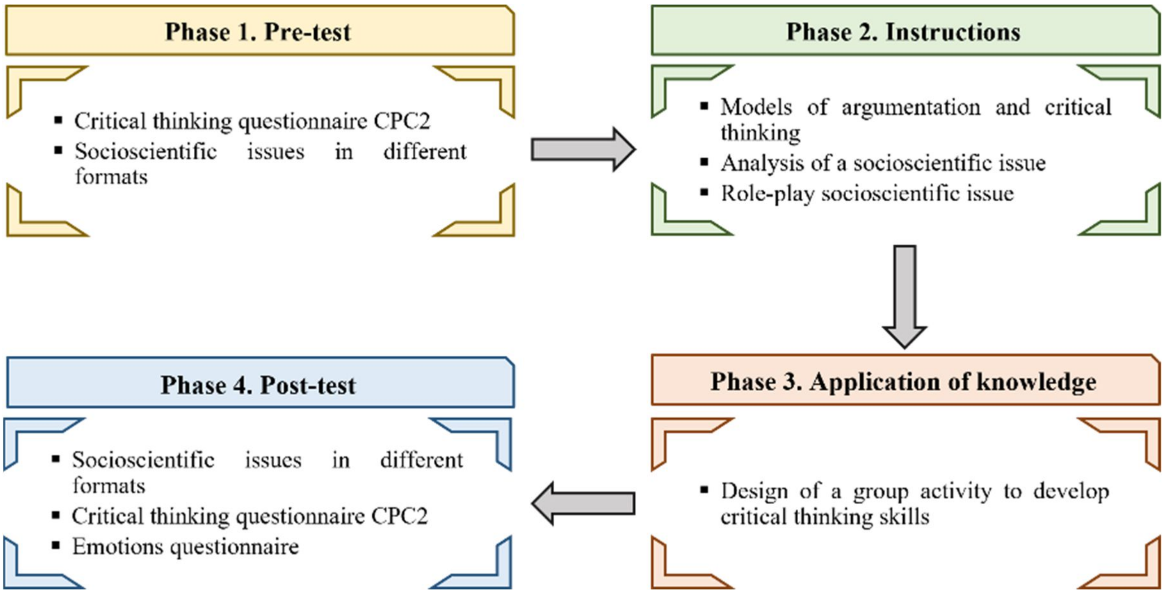

Figure 19. Phases of the critical thinking formative programme for pre-service science teachers.

Some examples of issues were the possible implantation of an artificial moon in China (Hierrezuelo-Osorio, Brero & Franco-Mariscal, 2021), the healthy or unhealthy nature of a vegan diet (Hierrezuelo-Osorio, Brero & Franco-Mariscal, 2020), the use of plastics (Hierrezuelo-Osorio, Cebrián, Brero & Franco-Mariscal, 2021) or the use of autonomous cars (Hierrezuelo-Osorio, Brero & Franco-Mariscal, 2021).

The issues were presented in different formats: text, video and opinions. The text format included two broad texts, one with arguments for and the other with arguments against the issue. Similarly, the video format included two short videos in favour of/against it. The opinion format provided short argued sentences from different roles involved in the problem. The pre-service science teachers also had the opportunity to design an issue to be implemented with secondary school students. Table 1 shows the characteristics of the three formats used for socio-scientific issues design.

The emotions felt by the pre-service science teachers in the development of the different activities with issues were investigated using an adaptation of the KPSI questionnaire (Martínez, Jiménez-Liso & Evagorou, 2019), where they had to choose one or several positive emotions felt (confidence, attentiveness, satisfaction, interest) or negative ones (insecurity, rejection, dissatisfaction, boredom, shame) and justifying their elections. It is a qualitative and quantitative tool simultaneously since it allows, on the one hand, to measure emotions, but from the student's vision. A percentage analysis of emotions was carried out, and positive emotions were compared with negative ones for each issue format.

Table 31. Characteristics to consider when designing socio-scientific issues in different formats.

Text	Video	Opinions
1. Defining the socio-scientific issue.		
2. Propose an initial decision on the problem (no access to information).		
3. To elaborate, from news items, two texts with opposing ideas on the problem to be dealt with, including different arguments for and against the problem that make the student think about it.	3. Find or edit two videos with opposing ideas about the problem with arguments for and against the problem. For classroom implementation, digital platforms such as *Coannotation* (Cebrián, 2016) can be used to annotate videos.	3. Draw up a set of opinions on the problem by specialists. Opinions from blogs/forums can also be included as long as they contain contrasted information with arguments for and against and allow for reflection on the issue.
4. Texts/videos/opinions should not necessarily be faithful copies of the original and may be adapted to avoid unnecessary information.		
5. It is important not to warn students of the contrasting nature of the texts/videos/opinions to prevent them from being influenced.		
6. Make a final decision on the problem after having analysed the information.		

RESULTS

Figure 2 shows the percentages of emotions felt by the pre-service science teachers after implementing the issue-based activities in the classroom in different formats (text, video and opinions). In general, positive emotions prevail in all formats (confidence, attentiveness, satisfaction and interest), especially in the text format (73.4%) compared to video (67.8%) and opinions (57.8%), which shows the good reception of this type of activities by the pre-service teachers.

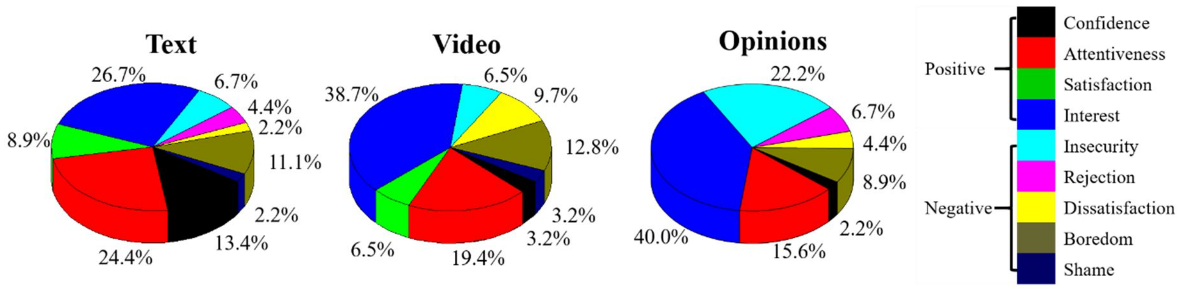

Figure 20. Emotions felt by pre-service science teachers in activities with issues in different formats.

If we focus on positive emotions, we see that interest is the main emotion, with values between 26.7% (text) and 40.0% (opinions). Some of the comments collected for this dilemma:

> *"I thought it was an efficient activity aimed at making students see that science is part of their daily lives"* [text format].

> *"I found it interesting to use audio-visual resources to develop and assess critical thinking"* [video format].

"I was interested since it was an issue, I disagreed with, but it also made me see other realities and act accordingly" [opinions format].

Attentiveness was the second most considered positive emotion, with values between 15.6% (opinions) and 24.4% (text). Regarding this emotion, the pre-service teachers commented that:

"High attentiveness was necessary to locate the arguments for and against the issue" [text format].

"Analysing every minute of the video brings high attention" [video format].

"I was reading opinions with which I was not very familiar, which meant that I had to focus on the content quite a lot in order to understand it" [opinions format].

Other minority positive emotions were confidence and satisfaction, and some comments in relation to these emotions were:

"*With audio-visual resources it is more entertaining and more attention-grabbing"* [confidence, video format].

"I find it a very interesting tool to use" [satisfaction, text format].

On the other hand, negative emotions are not so clearly in the majority in all formats. Boredom seems to remain constant in all three formats, with percentages ranged from 8.9% (opinions format) to 12.8% (video format). Some comments made by the pre-service teachers were:

"I don't think students are used to doing this kind of activity" [text format].

"I found it to be a heavier activity" [video format].

"I think it could have been a good activity to approach it in a different way" [opinions format].

Another major negative emotion was insecurity which remained between 6.5% and 6.7% in the video and text format respectively, reaching 22.0% for the opinions format. This last value can be attributed to the lesser amount of information provided in that format. In this case, the pre-service science teachers reflected that:

"Students are not used to critical thinking" [text format].

"Because only with videos, students cannot know the information well and have to argue a little bit for their own knowledge" [video format].

"I think it can give many faults from a technical point of view that can make the activity fail" [opinion format].

Other more minority emotions were rejection, dissatisfaction and shame with values below 10% in all formats. Some comments were:

"Students may be rejected by the fact that they have to deal with two long texts" [rejection, text format].

"*Since I found its use complicated to understand"* [dissatisfaction, video format].

In the case of shame, the students showed disagreement in relation to the content provided to carry out the activities. An example would be: *"I feel ashamed how someone is capable of* *saying so many barbarities without having any consequences, the worst of all is that there are people who, if they do not investigate in other sources, will take as true information that is totally wrong and built from a previous ideal"* [video format].

FINAL CONSIDERATIONS

This work has shown the emotions felt by pre-service science teachers when involved in the resolution of socio-scientific issues in different formats (text, video or opinions) that aim to develop their critical thinking.

Regardless of the issue's format, the pre-service teachers showed positive emotions, mostly interest and attentiveness. These results show the good reception of this kind of activities by the pre-service science teachers and show their usefulness to favour the teaching-learning process. In this sense, as a future line, we intend to investigate if the positive emotions of the pre-service science teachers influence the development of different critical thinking skills, especially in argumentation and decision making through the issues and the possible effect of each format.

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REDESIGN AND EVALUATION OF INSTRUCTION FOR PRIMARY STUDENTS' SOCIOSCIENTIFIC DECISION-MAKING TOWARD CONSENSUS BUILDING

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This study examined changes in the quality of primary school students' decisions on socioscientific issues (SSI) after undergoing relevant instruction designed to enhance their socioscientific decision-making towards consensus building. The instruction emphasised the generation of solutions for issues. We developed an SSI-based curriculum unit that provided primary school students training on socioscientific decision-making strategies toward consensus building. We implemented the curriculum unit over a two-year period and redesigned it in the second year. The participants were 63 and 68 Japanese primary school students (10 and 11 years old) in the first and second years, respectively. Before and after the unit, students worked on assigned tasks to measure the transfer of acquired decision-making competence to similar issues. The quality of students' decisions was analysed based on three components: supportive arguments, counterarguments, and solutions. We observed a post-instruction increase in the number of two-sided arguments containing solutions, especially in the second year. This study demonstrated that the instruction promoted students' socio-scientific decision-making toward consensus building. This study contributes to creating a strong research base that supports the curriculum and pedagogy suitable for primary students.

Keywords: Socioscientific issues, primary school, decision-making

INTRODUCTION

Socioscientific issues-based instruction for primary students

Socioscientific issues (SSI) represent complex social dilemmas related to the application of scientific principles and practices. The role of SSI has proven to be a major impetus in the promotion of scientific literacy within the science education community over the last two decades (e.g., Zeidler, Herman, & Sadler, 2019). A number of SSI-based instruction units have been developed for junior high and high school students, college students, and pre-service teachers (Fang, Hsu, & Lin, 2018), but only a few are available for primary school students (Evagorou, Sadler, & Tal, 2011). Kahn (2020) developed and implemented SSI units in the first, second, and fourth grade science classrooms over a one-year period. Ke, Sadler, Zangori, and Friedrichsen (2020) presented socio-scientific issues and model-based learning (SIMBL) as the framework for SSI instruction and demonstrated in detail how a third-grade student engaged in scientific modelling and socio-scientific reasoning. Nicolaou, Evagorou, and Lymbouridou (2015) interviewed sixth grade students individually at the end of instruction and explored their emotions about the learning environment. Karpudewan and Roth (2018) implemented eight SSI-based tasks to sixth grade students during a science curriculum and progressively measured students' levels of informal reasoning using an open-ended questionnaire. Nevertheless, there is a persistent lack of empirical research using quantitative data, and intervention studies with primary school students are even fewer.

Socioscientific decision-making

Decision-making about socioscientific issues involves the processes of considering the pros and cons of decision alternatives from multiple perspectives, including scientific, ethical, environmental, and social ones (Lee & Grace, 2012). In socioscientific decision-making, students first need to understand and describe SSIs in terms of their complexity; second, they are required to generate solutions that account for multiple perspectives on the issue; and third, they must critically evaluate solutions (Eggert, Ostermeyer, Hasselhorn, & Bögeholz, 2013). Fang et al. (2018) proposed a socioscientific decision-making framework that comprised three phases: formulating the decision-making space, positing a decision-making strategy, and reflecting on the decision-making process. Kim, Ko, and Lee's (2019) community-based SSI programme (SSI-COMM) included the phase of action taking, wherein students looked for and implemented the best solutions to the issue.

Science education research has identified the ability to use trade-offs as a crucial aspect of socioscientific decision-making (e.g., Eggert & Bögeholz, 2010). The use of trade-offs is characterised by the ability to consider and compare the advantages and disadvantages of multiple options and is described as a compensatory decision-making strategy. In contrast, intuitive decision-making was characterised by the use of non-compensatory decision strategies (cut-offs), that is, considering one criterion at a time. Some studies surveyed primary school students' decision-making approaches using written tasks (Papadouris & Constantinou, 2010; Xiao, 2021). Papadouris and Constantinou (2010), for example, investigated sixth-grade students' approaches to compare rival solutions in several socioscientific decision-making contexts and demonstrated that they could not consistently select an effective decision-making approach to different socioscientific tasks.

Various instructional interventions have been developed to support students' use of appropriate decision-making strategies, such as introducing an optimisation strategy (e.g., Böttcher & Meisert, 2013) and using additional meta-cognitive approaches (Eggert et al., 2013; Gresch, Hasselhorn, & Bögeholz, 2013). Intervention studies that focus on young students' decision-making skills help them apply the optimization strategy (Nicolaou, Korfiatis, Evagorou, & Constantinou, 2009; Papadouris, 2012). Moreover, these studies have focused on choosing the best option among possible solutions rather than developing new alternative solutions. To overcome this issue, there is a need for further studies on socioscientific decision-making to create a strong research base that supports the curriculum and pedagogy suitable for primary students.

The aim of this study

Therefore, this study examined the effect of SSI-based curriculum units on the quality of primary school students' decisions on socioscientific issues, that is, to ascertain how and whether engaging an instructional intervention enhances primary students' socioscientific decision-making towards consensus building. Socio-scientific decision-making towards consensus building, in this study, emphasises generating solutions to resolve issues. We developed an SSI-based curriculum unit for primary school students, wherein the students identified multiple conflicts among various stakeholders' opinions and proposed solutions to resolve them by focusing on consensus building. The training on socioscientific decision-making strategies in a cooperative learning setting with embedded metacognitive questions (Eggert et al., 2013), and previous studies on socioscientific action taking (Kim et al., 2019) serve as the theoretical background of this intervention. We implemented the unit in the first year, and then redesigned it for the second year based on the students' performances in the first year. The effects of this curriculum unit were measured with a paper-and-pencil task on the transfer of acquired decision-making competence to similar issues.

METHODS

Participants

For the first year, we recruited 63 students (30 girls and 33 boys) in the fifth grades (10-11 years of age) from two classes at a national university-affiliated elementary school in the Kansai region. All the students were Japanese and had a middle-class socioeconomic background. The second-year students included 68 fifth-grade students (35 girls and 33 boys) in the same primary school. All of them were Japanese, except for one Russian girl. The students were given tasks in Japanese and they answered them in Japanese, as it was their language of instruction. In Japan, primary science begins in third grade (8–9 years of age). The students had not received any SSI instruction prior to this study.

The students' regular science teacher taught the SSI-based curriculum. He had taught science for nearly 13 years. The head of the school recognises the participating teacher as a teacher with excellent content knowledge and instructional strategies for regular science classes, while not having much experience teaching SSI.

Curriculum unit

The goal of the curriculum unit was to provide primary school students with the training on socioscientific decision-making strategies towards consensus building, that is, the generation of two-sided arguments containing solutions to resolve multiple conflicts. For this purpose, we selected the genetically modified organisms (GMOs) as the focal issue and conducted collaborative sessions to discuss this matter.

The content of the instructional sequence is presented in Table 1. The curriculum unit consisted of 18 lessons (each 45 minutes) and included two phases. Phase 1 included an information search for science ideas surrounding the issue and arguments for both sides. The students learned about the scientific background of the process and treatment of allergies and GMOs. They then explored opinions favouring or opposing the focal issue, thus examining the benefits and drawbacks of the genetic modification technology. The favouring or opposing opinions were taken from a doctor, patient, scientist, farmer, and so on. We created eight dialogue-videos to help students understand the explanatory materials provided by each stakeholder. Students viewed four dialogue-videos at a time, read the corresponding materials, and then discussed the content of the videos in pairs. In phase 2, the students were provided with a decision-making strategy for consensus building and had to apply it correctly to cooperative learning settings. They clarified the complex relationships among the views, and identified concerns and conflicts among stakeholders. The students were guided to identify three concerns: economy, treatment or health, and environmental impact. Finally, they engaged in group activities for consensus building. They were provided with worksheets containing scaffolding to construct solutions and reviewed these solutions via peer critique from the perspective of whether each stakeholder was convinced. They tried to expand solutions that could convince multiple stakeholders and reach a consensus.

After reviewing the first year's implementation, we partially improved the learning materials and activities in Phase 2. The first improvement was the assessment and review of students' solutions through peer critique, that is, reflection on the decision-making process (Fang et al., 2018). It was because a few intervention studies fostering decision-making competence emphasised metacognitive reflection about the decision-making process and the nature of decision-making strategies (Böttcher & Meisert, 2013; Eggert & Bögeholz, 2010). We improved the content and layout of the worksheets used in the learning activity to more clearly scaffold the activity of examining whether each stakeholder was convinced with the proposed solution and the activity of revising the solution through peer critique. In addition, we held two lessons for each conflict to ensure sufficient time for the activities. The second improvement concerned decision-making strategy training. After the completion of activities for consensus building around the focal issue, the lesson to facilitate the transfer of learning was added. Students were provided with four new SSIs on papers and they adapted the decision-making strategy for consensus building into one of them. New SSIs were created as isomorphic problems for the focal issue; the contexts were security cameras, mega solar, invasive species, and swine fever vaccine. Each student selected one issue and constructed arguments adapting the decision-making strategy they learned. With these improvements, the curriculum unit in the second year consisted of 22 lessons.

Table 1. The content of the instructional sequence and corresponding elements of the instructional model.

Phase	Contents and learning activities in this programme
1. Information search	Japanese cedar-pollinosis-alleviating rice (i.e., a functional rice developed through genetic modification to alleviate cedar pollinosis allergy.)
	- Learn about the scientific process and treatments of allergies, and the GMOs. - Explore opinions favouring or opposing the focal issue and examine the benefits and disadvantages of genetic modification technology.
	Learn using materials on YouTube and the dialogue-videos that contained each stakeholders' opinion around the issue.
2. Decision-making for consensus building	Clarify the complexity of relationships among views and identify concerns and conflicts
	Construct solutions to resolve conflicts and revise these solutions through peer critique.
	Only the 2nd year: Practice to adapt the decision-making strategy for consensus building into new SSIs.

Socioscientific decision-making task

The students in both years were assigned a task on the transfer of acquired decision-making competence to similar issues before and after the unit. This task included a different SSI from that in the curriculum unit: to determine whether local governments should provide subsidies to encourage the purchase of electric vehicles (EVs). The students read background information on EVs and stakeholders' opinions on convenience, and the economic and environmental aspects. In order to assess their spontaneous decision-making behaviour, we asked them to construct arguments as though they were making a decision on behalf of the local governments regarding subsidies to encourage the purchase of EVs.

Analysis

Few studies have quantitatively analysed students' written arguments on socioscientific decision-making. Evagorou (2011) suggested the following six levels to analyse students' artefacts: level 1 – arguments consisting of a simple claim versus a counterclaim or a claim versus a claim; level 2 – arguments consisting of a claim versus a claim with either data, warrants, or backings, but without rebuttals; level 3 – arguments consisting of a series of claims or counterclaims with either data, warrants, or backings with the occasional weak rebuttal; level 4 – arguments with a claim and a clearly identifiable rebuttal. Such an argument may have several claims and counterclaims at level 5, and an extended argument with more than one rebuttal at level 6.

In this study, data or warrants were provided as opinions favouring or opposing the focal issue, and students were expected to choose and describe some of them as supportive arguments or counterarguments to justify their decision. Moreover, students were encouraged to generate solutions to resolve the issue (Eggert et al., 2013), instead of rebutting their opponents. We analysed the quality of students' decisions using three components: supportive arguments, counterarguments, and proposal of solutions. Eggert et al.'s (2013) scoring guide for the assessment of students' solutions rated a solution on the basis of two or more aspects higher than a solution on the basis of one solitary aspect, and a solution on the basis of two aspects with an even higher relation. Informed from the rubric of Evagorou (2011) and Eggert et al. (2013), the evaluative rubric of the decision-making level is presented in Table 2. The rubric comprises six levels, the lowest of which includes only an unsubstantiated claim. Successive levels include supportive arguments, counterarguments, and solutions. Proposals of detailed solutions were categorised as being at a 'higher level' if they also intended to resolve multiple conflicts.

We take the description in the last line of Table 2 as an example to illustrate the evaluative process. The learner chose a position in favour of subsidising the purchase of electric vehicles [*claim*] and justified it with the following *supportive arguments*: EVs are more environment friendly than gasoline-powered cars because they emit less carbon dioxide; they are more economical because the price of electricity is relatively stable; and they are convenient to use because many gas stations have charging spots. The learner also described *counterarguments* related to convenience and environmental concerns. Based on these facts, she proposed a *solution* to resolve each conflict. For environmental concerns, she suggested the use of solar power, and for concerns of convenience, she suggested the creation of maps and signs showing the locations of power generation spots. In summary, we rated it as Level 5 because it generated two-sided arguments and proposed solutions to resolve multiple conflicts.

Table 2. Rubric for assessing the decision-making level and examples from this research.

Level	Description	Examples
0	Made only simple claims, without justification.	Our city does not provide subsidies [*claim*]. If I have an accident with my EV, I might lose the deposit and the cost of charging the car. (The following is omitted)
1	Made claims justified by supportive arguments, but there were no counterarguments (one-sided arguments).	Our city does not subsidize for EVs. The reason is, it takes time to recharge the battery and one has to wait while other cars are being charged [*supportive argumen*ts]. (omission) EVs are not environment-friendly because they involve disposal of spent fuel from nuclear power generation and carbon dioxide emissions from thermal power generation [*supportive argumen*ts].
2	Generated supportive arguments and counterarguments (two-sided arguments).	Our city will provide subsidies. EVs are superior in that they emit no carbon dioxide while running and are environmentally friendly. Besides, the fuel cost is low, which helps the citizens economically [*supportive argumen*ts]. Although carbon dioxide is generated during power generation [*counterarguments*], it is less than that of gasoline-powered vehicles, so EVs are more suitable for improving the global environment [*supportive argumen*ts]. Therefore, they should be subsidized.
3	Generated two-sided arguments and suggested the need for a proposal to resolve some conflicts.	Our city will not provide subsidies because they think EVs are not environment-friendly [*supportive argumen*ts]. In order to meet our power needs, we have to produce electricity at power plants, which causes problems such as the disposal of spent fuel from nuclear power plants and increased carbon dioxide emissions from thermal power plants [*counterarguments*]. (omission) I think we can go to towns that use EVs and gather feedback while also testing the air quality of the town [*suggest a need for solutions*]. EVs do not emit carbon dioxide, but the community as a whole emits a lot of carbon dioxide.
4	Generated two-sided arguments and constructed a solution to resolve one conflict.	Our city will subsidize it. There is an objection that it takes a lot of time and effort to find out where the charging facilities are [*counterarguments*]. To solve this problem, we can create a map showing the locations of charging facilities [*solution to resolve conflicts: Convenience*]. (omission) Considering the time of power generation, carbon dioxide emissions are not zero [*counterarguments*], but they are very low compared to conventional cars. Thus, we can say that the car is environment-friendly [*supportive argumen*ts]. Our town will therefore provide subsidies.
5	Generated two-sided arguments and constructed a solution to resolve multiple conflicts.	Our city subsidizes EVs. This is because EVs are economical as they use electricity at a stable price, are environmentally friendly because they emit less carbon dioxide than cars that run on gasoline, and many gas stations already have charging facilities anyway [*supportive argumen*ts]. However, opponents point to the inconvenience of having to seek out charging facilities in unfamiliar places and the fact that power plants emit carbon dioxide [*counterarguments*]. In order for EVs to become more convenient and more environment- friendly, I suggest attaching solar power to cars and houses. Using nature's power to generate electricity further reduces carbon footprint and improves environmental friendliness [*first solution to resolve conflicts: Environment*]. In addition, finding charging facilities in each city should be made easier by posting maps and signs indicating their location [*second solution to resolve conflicts: Convenience*].

RESULTS

For the decision-making level scores of socioscientific decision-making tasks in the pre- and post-test segments (see Figure 1), we conducted two-way ANOVAs with POSITION (for and against) and YEAR (first and second). We found that in the pre-test segment, students who agreed to the issues had higher-quality decision-making abilities than those in opposition ($F(1,127) = 13.580$, $p<.001$). Further, in the post-test segment, students in the second year outperformed those in the first year ($F(1,127)= 4.120$, $p<.05$). Moreover, the interaction effects were found to be nonsignificant in both tests.

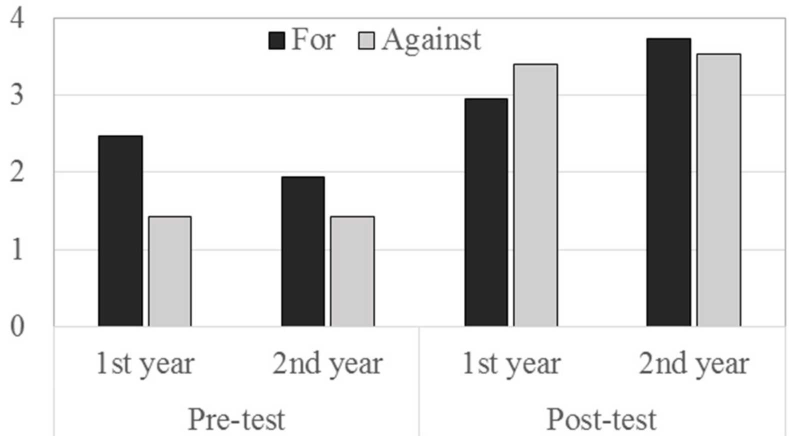

Figure 1. Mean score of the levels of the students' decisions by approval or disapproval of the issue.

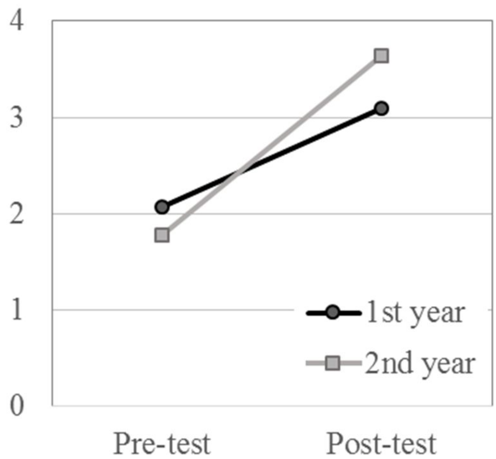

Figure 2. Mean score of the levels of the students' decisions in the pre- and post-tests.

Figure 2 shows the mean scores of decision-making of all the students. The two-way ANOVA revealed the statistical effects of TEST (pre and post) and the interaction effects between TEST and YEAR ($F(1,129)=110.927$, $p<.001$; $F(1,129)=8.989$, $p<.001$), but not in YEAR ($F(1,129)=.602$, *n.s.*). The post hoc test showed that the increase in levels after the intervention was significant in both years. In addition, while the mean scores of the pre-test did not differ by year, the post-test level scores of the second year were higher than those of the first.

DISCUSSION AND CONCLUSION

We developed an SSI-based curriculum unit for primary school students to learn about socioscientific decision-making strategies toward consensus-building. Students were trained in socioscientific decision-making strategies in a cooperative learning setting and reviewed their solutions with metacognitive scaffolding. The effects of this unit were measured using the transfer task. The results from the socioscientific decision-making tasks showed that the instructions developed for this study promoted the quality of students' socioscientific decision-making toward consensus building. In the pre-test segment, the decision-making levels of the students who opposed the promotion of the purchase of EVs were lower in both years. However, in the post-test segment, both students who agreed and those who disagreed generated two-sided arguments containing solutions, and the difference between them disappeared. The effect was especially large in the improved instruction, which was implemented in the second year. Helping students to reflect on their decision-making process and providing them with more experience in adapting to the decision-making strategy were effective.

This study contributes to creating a strong research base that supports the curriculum and pedagogy suitable for primary students. Future work should analyse data on learning activities in the curriculum unit and their relationship to performance in decision-making tasks.

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THE EFFECTS OF A SOCIO-SCIENTIFIC DECISION-MAKING INTERVENTION ON GREEK STUDENTS' KNOWLEDGE AND ATTITUDES TOWARDS VEGETARIANISM

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This paper reports on the effect of a socio-scientific decision-making intervention on Greek primary school students' knowledge and attitudes towards vegetarianism. A number of 190 6th grade students from four primary schools in Greece enrolled in a pre-test post-test socio-scientific decision-making intervention that aimed to improve their decision-making skills. Vegetarianism was chosen as the main topic of the intervention for two main reasons: (1) there are limited studies looking at children's knowledge and attitudes towards vegetarianism and (2) Greece has one of the highest rates of childhood obesity in Europe partially because of heavy in meat diet followed by children and young people. The results show that students improved their vegetarianism knowledge scores at the post-test, but this improvement was not found significant. This finding shows that exposing students in the knowledge is not merely enough to improve their knowledge and more focus should be given to content knowledge when students engage in socio-scientific decision-making. However, it seems that students shifted their attitudes towards adopting a vegetarian diet. More specifically, 20% of the students stated that they had thought of the possibility of becoming vegetarians at pre-test, while double the proportion of students (41%) reached a decision in favour of adopting an only-vegetarian policy at their school after having been exposed to the arguments in favour and against vegetarianism. This is an important finding that can inform diet-related interventions to reduce children's daily meat intake and improve their diet habits, which is of crucial importance for the Greek context

Keywords: socio-scientific issues, decision-making, vegetarianism

INTRODUCTION

An important aim of science education is to train students to be participatory citizens who are able to make systematic and well-informed decisions about issues concerning the society (Gresch et al, 2013). Socio-scientific issues can be defined as the issues that have a basis in science and can potentially impact society. In general, socio-scientific issues refer to real-world scenarios that are complex issues with no definite answers, including scientific knowledge, personal values, and ethical reasoning. Apart from encouraging decision-making, socio-scientific issues can improve critical thinking and provide an appropriate context to teach science content (Zeidler & Nichols, 2009). The purpose of this study is to explore whether a socio-scientific decision-making intervention has an effect on students' socio-scientific knowledge and attitudes.

Examples of socio-scientific issues that have been used in studies are wind energy (Sutter et al, 2019), genetically modified food (Bottcher & Meisert, 2013) and natural selection and antibiotic resistance (Peel et al, 2019). The main socio-scientific issue that was used in this study is vegetarianism for its theoretical and practical importance for the Greek context. Although there has been extensive research establishing adult vegetarians' conceptions and attitudes towards vegetarianism in Western countries like the USA and the UK, there are limited studies focusing on young children from different cultural backgrounds (Rosenfeld, 2018), with no other study found in the Greek context. What is more, young Greek people turn to fast food options that are largely meat-based (Papadaki et al, 2007), while the frequency of meat consumption is particularly high, with the presence of meat on the plate for almost every occasion in Greek family and social life. Data from the WHO 2009/2010 survey in 53 countries revealed that Greece comes second after the USA in childhood obesity with one in four 11-year-old boys (26%) and one in five girls (18%) classified as obese or overweight as well as is the leading European country for childhood obesity with 33% of 11-year-olds (both genders) being obese or overweight (WHO, 2015). This trend indicates the need for diet-related research with Greek children in order to establish a baseline of their current knowledge and attitudes so as to design culture-appropriate interventions to improve their dietary habits.

METHOD

Participants

A total of 190 Year 6 participants (11-12 years old) from four different public primary schools in a semi-urban area with a population of 75,000 citizens in central Greece participated in the present study. The participating schools were typical in terms of academic ability, and socio-economic resources. The sample consisted of 57% male and 43% female participants. The study obtained approval from the Research Ethics Committee of the Faculty of Education University of Cambridge and the Greek Ministry of Education and Religious Affairs. Parents completed opt-out forms and students gave their ascent.

Procedures

The students participated in a larger PhD project (Tsapali, 2019) on decision-making on socio-scientific issues that was classroom intervention-based, lasting approximately one month for each school. A pre-test, post-test, delayed post-test design was followed with the intervention spaced across three sessions over two weeks (for an overview see Tsapali & Ellefson, 2019). Figure 1 shows the different intervention sessions and data collection time-points. At pre-test, students were tested on their knowledge and attitudes towards vegetarianism as well as on their pre-existing decision-making skills. During session 1, students were presented through PowerPoint slides with four arguments in favour and four arguments against vegetarianism from four different categories (animal life, diet/health, environment, and human evolution). Students had the opportunity to explore the arguments and ask questions to comprehend them. During Session 2, students were taught a compensatory decision-making strategy and had to apply it to make a decision about vegetarianism. During this process, they had to use the arguments in favour and against vegetarianism and fill in a decision-making matrix with the options and the criteria relevant to their decisions. A few days later and after one more session (session 3) in which students had the opportunity to practise their decision-making strategy, they completed the post-test which included two questions referring to the associated risks and benefits of vegetarianism.

Figure 1. Overview of intervention and data collection time-points. The highlighted parts refer to the vegetarianism knowledge and attitudes collection time-points.

Students' knowledge of vegetarianism was examined at the pre-test and post-test through two open-ended questions. Table 1 shows the questions that were used to elicit students' knowledge of the benefits and risks of vegetarianism, followed by the scoring scale and relevant examples. Students were asked to think of any benefits and risks associated with vegetarianism that they know of. Students were assigned a score of 0-2 for each of the questions pending on their knowledge of potential risks and benefits associated with vegetarianism. Students' attitudes of vegetarianism were examined at two instances: 1) at the pre-test with an open-ended question (Have you ever considered becoming a vegetarian?) and 2) at the end of Session 2 after completing the vegetarianism scenario in which they had to make a decision on whether they would accept an only-vegetarian meals policy in their school cafeteria. Students' decision was recorded to represent their attitude towards vegetarianism after being exposed to the arguments in favour and against.

Table 1. Scoring scheme for vegetarianism knowledge.

Question	Scoring	Score Description
Do you know of any benefits associated with following a vegetarian diet?	0-2	0: No answer/irrelevant/ Answer includes positive response but with no explanation 1: Answer includes specific benefits associated with vegetarianism from one group of arguments. For example: *it is good for our heart* 2: Answer includes specific benefits typically associated with vegetarianism from two or more groups of arguments. For example: *we will have better health and get protein from other vegetarian food*

Do you know of any risks associated with following a vegetarian diet?	0-2	0: No answer/irrelevant/ Answer includes negative response but with no explanation 1: Answer includes specific dangers associated with vegetarianism from one group of arguments. For example: *it can cause very serious health problems* 2: Answer includes specific risks typically associated with vegetarianism from two or more groups of arguments. For example: *if they (vegetarians) are not cautious they might not be getting all the nutrients and in this way to have many health-related problems*

Data analysis

For the purpose of this analysis, two variables were used: students' vegetarianism knowledge at pre-test and students' vegetarianism knowledge at post-test. These two variables represent students' content knowledge of associated risks and benefits of vegetarianism at the pre- and post-test timepoints. All the assumptions were explored before proceeding to the main analysis.

A paired-sample t-test was performed to identify whether there were any significant differences between students' content knowledge of vegetarianism scores between the pre- and post-test. In other words, the analysis aimed to examine whether the intervention had any effect on improving students' knowledge and understanding of the associated benefits and risks of vegetarianism.

For students' attitudes, we looked at students' individual decisions right after the decision-making intervention, for which students had to apply the taught strategy and make a decision regarding the vegetarianism scenario and compared them to their responses regarding adopting a vegetarian diet at the pre-test. No statistical analysis was employed here as students responded to different questions in the two instances.

RESULTS

Knowledge

Overall, 177 students responded to both the pre-test and post-test. On average, participants scored higher on the post-test (M = .68, SE = .06), compared to the pre-test (M = .56, SE = .05). This difference, -.12, was found non-significant, $t(176) = -1.36$, $p = .18$.

Attitudes

The data presented here refer to 167 students who completed all the relevant worksheets and questions. Table 1 illustrates that almost half of the students stated that they would not become vegetarians after reviewing the arguments in favour and against vegetarianism but interestingly 40 per cent of the students stated that they would accept an only-vegetarian policy in their school and 6 per cent of them said that they would opt for both vegetarian and non-vegetarian meals at school. At pre-test, only 21 per cent of students had thought of the possibility of becoming a vegetarian but they still noted that they would go for that choice, while after the intervention almost double the number of students stated that they would accept having only vegetarian meals at school. What is more, at pre-test, 79 per cent of the students stated that they have not thought about the possibility of becoming a vegetarian in the past or they don't want to be, but the equivalent number after the intervention was 54 per cent, which indicates some shift in their attitudes towards vegetarianism.

Table 2. Frequencies and percentages of students' responses before (pre-test) and after the intervention (intervention worksheet) regarding their attitude towards vegetarianism.

Question	Yes		No		Both	
	f	%	*f*	%	*f*	%
Have you ever considered becoming a vegetarian? (Pre-test)	35	21	132	79	-	-
Would you accept an only-vegetarian food policy in your school? (Intervention worksheet)	67	40	90	54	10	6

DISCUSSION

The findings indicate that the decision-making intervention did not have a significant effect on students' improving their knowledge of vegetarianism. Possible explanations could be that students that were exposed to the content briefly and that they had to work on the decision-making strategy which potentially led to an increase in their working memory load, and they did not have much memory space to process the vegetarianism content (Sweller, 2003). This finding shows that exposing students in the knowledge is not merely enough to improve their understanding of it, and more focus should be given to content knowledge when students engage in socio-scientific decision-making. However, students' attitudes towards vegetarianism seem to have shifted as the number of students thinking positively about adopting an only vegetarian meal policy in their school grew considerably.

One of the main limitations of this study is that students' attitudes towards vegetarianism were measured through a few questions in a worksheet and thus, the reasons behind students' responses could not be explored further. Future qualitative research looking at students' attitudes in more depth through interviews, for instance, could provide more context to the observed change and shed light on students' thinking processes.

Overall, the findings of this study show the potential of such socio-scientific decision-making interventions to reduce children's daily meat intake and improve their diet habits, which is of crucial importance for the Greek context.

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CONCEPTION OF BIODIVERSITY VALUES IN PRE-SERVICE SCIENCE TEACHERS ON A SOCIO-SCIENTIFIC DISCUSSION

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This study aims to assess pre-service teachers' values of biodiversity during a training course. The focal group was used as the methodological approach for stimulating the debate about the socioscientific problem of disappearance of bees. This topic of discussion was chosen because it is caused by the indiscriminate use of pesticides in agriculture, and we are experiencing a moment of flexibility in the use of these chemicals in Brazil. Considering this context, it is necessary to highlight the discussion about the values of biodiversity, especially in a pre-service science teacher preparation course. The discussions were mediated by the questions: 1) What is the importance of bees for the environment and society? 2) What causes the bees to disappear? 3) What are the consequences of using pesticides? The participants' speeches were recorded, transcribed, and analyzed according to four categories of biodiversity values: instrumental, eudaemonic, moral intrinsic, and absolute intrinsic. After the analysis, a total of 76 occurrences of values were identified (instrumental - n = 22, eudaemonic - n = 2, moral intrinsic - n = 25 and absolute intrinsic - n = 27). Scientific education plays an important role in the acquisition of biodiversity values, especially moral and absolute intrinsic ones. Hence, it is important to foster high-quality teacher training so that pedagogic practice promotes biodiversity values in children and teenagers. This study may contribute to educational propositions based on citizen empowerment for more just, ethical, and responsible actions regarding biodiversity issues.

Keywords: Teacher Preparation, Values in Science Education, Environment

INTRODUCTION

Biodiversity can be defined as the variety of forms living in nature that exists as a result of an evolutionary process (Wilson, 1992). The human being is dependent on the resources that come directly and indirectly from nature, and yet, its action has played a significant role in modifying ecological processes and in environmental degradation (Alho, 2008). The role of biodiversity is complex and environmental degradation can affect countless other ecosystem components. Economic, social, and political consequences affect populations unevenly. In these situations, we face diverged interests linked to the conservation of biodiversity. In this respect, economic, ecological, and ethical reasons can be cited (Léveque, 1997), based on moral, philosophical, and political arguments that seek to attribute values to biodiversity.

According to Wiegleb (2002), the term "biodiversity" always has an evaluative connotation, allowing different groups to define it according to its bias. The author performed a bibliographic review of the values of biodiversity from an ethical perspective of nature, looking for relationships between the currents of thought arising from economics and philosophy. He proposed four values to the biodiversity: the instrumental value is associated with direct and indirect use, from necessity of basic elements, from food to ecological functions of a given ecosystem; eudaemonic value is related to human well-being, e.g. aesthetic, emotional, and religious values; moral intrinsic value is related to the moral obligations of the human being with other species; absolute intrinsic value is derived only from the properties of the object itself, such as diversity and individuality.

Table 1. The values of biodiversity and its meanings adapted from Wiegleb (2002).

Value of biodiversity	Meaning
Instrumental value	associated with direct and indirect use, from the need of basic elements, such as food, even the ecological functions of a given ecosystem. Includes nutrition, pharmacology, raw material, scientific use, and nature's services;
Eudaemonic value	related to human well-being, including aesthetic, emotional and religious values. Also includes peculiarity, originality, beauty, symbiosis with nature, conviviality, divinity (holiness) of nature, and unity of the creation;
Moral Intrinsic value	related to the moral obligations of the human being with other species. Includes egoism, anthropocentrism, pathocentrism, biocentrism, physiocentrism, and cosmocentrism;
Absolute Intrinsic value	derived only from the properties of the object itself, such as diversity and individuality;

We believe that the absence of values of biodiversity or exacerbated focus on instrumental values may be detrimental to the environment. Among the anthropic actions of ecosystem degradation, we mention the indiscriminate use of pesticides, whose side effects can be related to the disappearance of bees due to behavioral changes and possible residual effects (Tadei et. al., 2019). In Brazil, the reduction in the bee population affected several wild species in the biomes (Tadei et al., 2019), and we live in a time of flexible production, commercialization, and use of these chemicals. Such public guidelines contribute not only to bee issues but also to public health problems and the monopoly of agricultural inputs. Besides, the economic and social impact linked to the disappearance is alarming since these insects pollinate plants of economic interest for food production, as well as maintain plant biodiversity in different biomes (Tadei et al., 2019; Puig & Evagorou, 2020).

We can observe that the context in which the problem is inserted in Brazil is an emerging one. It requires a critical discussion focusing on a scientific and political vision, since this is a real problem that can affect student's lives. The school must address problems such as this aiming at the formation of critical citizens. In addition, it allows students to question and discuss concrete socio-political problems from a scientific basis and, thus, have robust arguments for their action and participation in society.

Considering the severity of the environmental impacts caused by human activity, the need for people to value biodiversity, and the importance of teachers in the science education process, our goal in this study is to assess pre-service teachers' values of biodiversity during a teacher training course in Brazil.

METHODS

This study involves a qualitative research approach and results in descriptive data. It intends to raise the conceptions of pre-service science teachers about the values of biodiversity. The participants of the research were science and biology pre-service teachers in a training course that took place in the city of Ribeirão Preto, Brazil.

The focal group was used as the methodological approach for stimulating the debate about the disappearance of bees and providing the explanation of spontaneous conceptions arising from the process of interaction and opposition of the subjects' ideas. It allows participants to express their opinions about another member's speech, jointly constructing their arguments (Stewart & Shamdasani, 2014). According to Hodson (2018), it is important to develop discussions to assess the impacts due to technology and cultural changes, health risks, and environmental degradation; which are considered as ethical-moral dilemmas that can decrease the power of choice and freedom.

The focal group

A problem-solving situation was chosen to promote decision-making on emerging aspects in society. In this perspective, the socio-scientific theme of the disappearance of bees was chosen due to its relation with social and environmental issues, being a problem that permeates the theoretical framework of this research in a meaningful way.

Based on the presented theoretical-methodological contribution, a focal group was built, consisting of mediation materials composed of preliminary questions: 1) What is the importance of bees for the environment and society? 2) The use of pesticides - What causes the bees to disappear? 3) Legislative aspects on the production and commercialization of pesticides in Brazil - What are the consequences for the environment and society? (Freitas, Nascimento, Castro, & Motokane, 2020).

The analysis

In this study, we use the data obtained from the participant's interactions in two different focal groups. All interactions of both focal groups (n_1 = 10, n_2 = 6) were recorded and transcribed according to guidelines presented in Preti (1999). An episode is a portion of the speech with clear limitations within a theme, tasks or didactic phase. The episodes were subdivided into turns, smaller units of analysis, which present the subjects' speeches. Finally, the speaking shift was considered as the period in which speech changes between interlocutors during the dialogue (Preti, 1999).

Episodes in which participants manifested biodiversity values were considered for analysis. Every speech was read and classified according to Wiegleb's (2002) four categories of values: instrumental, eudaemonic, moral intrinsic, and absolute intrinsic. The total number of occurrences of each value was counted and the results were furtherly discussed in the light of the theoretical framework.

RESULTS AND DISCUSSION

A total of 76 occurrences of values were identified in 50 utterances among focal groups. They were divided into instrumental (n = 22), eudaemonic (n = 2), moral intrinsic (n = 25) and absolute intrinsic (n = 27) (Figure 1). In some utterances, more than one value was identified. Instrumental and moral intrinsic co-occurred 7 times, instrumental and absolute intrinsic, 4 times, moral and absolute intrinsic, 15 times, and moral intrinsic and eudaemonic, once. 7 statements were identified as criticizing human action driven by instrumental values.

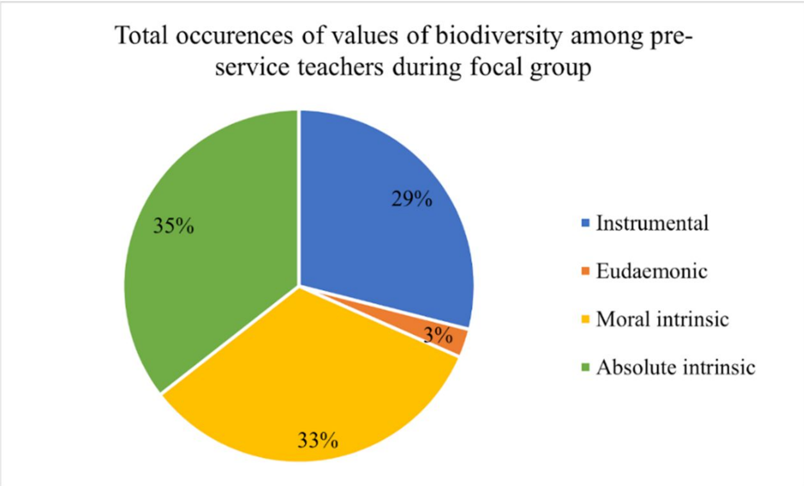

Figure 1. Circle chart picturing percentage of each of the four values of biodiversity about a total number of occurrences.

In the following, we exemplify each category and co-occurrences by illustrative quotations from participants' interactions during focal groups.

- Instrumental value

  *I think people don't know, don't see this relationship between pollination and the food in our table. (FG1 – S3)**

  There is a study that says that, without bees, ninety percent of food production would be impossible. (FG2 – S9)

  (*) the codification includes the code of the sample group (Focal group 1 or 2) following with the number identifying the participant in the group.

- Eudaemonic value

  I'm against it because of the social issue...I think it's very wrong for you to try to replicate a living being using technology. You're going to use that for bees, then the other species is becoming extinct, instead of trying to preserve it, let's replace it. I don't know what this could turn into. (FG2 – S15)

- Moral intrinsic value

  It depends on what you have, because sometimes you want to produce a lot of honey and you end up exploiting this bee in a way, I don't know if it's free enough for the bees to be in your home (FG1 – S4)

  Individual action... in addition to changing the view, I think we can make our neighborhood aware, try to find out which plants the bees pollinate and have them here in our neighborhood, you know...small actions that help. (FG2 – S15)

- Absolute intrinsic value

  I think that if such exchange exists, there will be more variability, there will be more variations and I think that's what contributes to the appearance of more different types of species. Because of a great variation in plants, then at one point you can generate a new species… self-fertilizing and have genetics… I think this contributes to new species (FG1 – S2)

  It will participate in some food chains, right... so this species ends up being affected (FG2 – S10)

- Instrumental and moral intrinsic values

  They are releasing a lot of pesticides and this contributes to the death of bees, then these people understand that in addition to being bad for health, pesticides also contribute to this mass death and to the end of food. Maybe people could value more organic food and start to buy more of them. If people don't buy non-organic food, sales start to drop and maybe this impacts the production of pesticides and then it kind of generates a cycle to use less pesticides. (FG1 – S4)

- Instrumental and absolute intrinsic values

  I think this issue of pollination is more obvious because whether you like it or not it would affect the majority of people directly. And not just the pollination of plants and fruits that we consume. They also pollinate others that are not for human consumption and this would also be affected and would affect the food chain in general...not just us and the food issue...so there is a lot of this ecological imbalance that can cause and interfere in a food chain. (FG2 – S13)

- Moral intrinsic and absolute intrinsic values

  I think that I would still not support it because it would convey the idea that everything in nature, all cycles can be replaced with something. So just as today we talk about the importance of preserving bees and then one day, they are extinct and we are able to supply this, it will imply that everything we believe in conservation can be resolved, so I think it will cause a collapse in society of not wanting to take conservation and preservation issues seriously. (FG1 – S3)

- Moral intrinsic and eudaemonic values

  A very basic thing is that insects and other animals that are considered fluffy and cute would be taboo, especially in childhood. So, there's a child playing and there's a little bee nearby, sometimes she gets scared and then she creates a fear of several flying animals. So, I think that it's necessary to change the relationship of children with insects since early stages of education. I also think that it is something that in the future, when the child becomes an adult, he/she will have a better relationship with that little animal, he/she sees a bee and doesn't want to kill her, for example. And the fact that the video also brings the possibility of raising bees in your house, I think many people would never do it because they would be super scared because 'it will sting me'. Even though it's a stingless bee, people still don't believe that the bee won't do they any harm. (FG1 – S3)

- Criticizing instrumental values

  This happens a lot, people determining whether a thing is valid or not valid if it exists or if it's preserved for its economic value. This way of thinking is very problematic because not everything has to have economic value, right? If things exist it's because they exist...We taking away... creating ways to make money with these things... things were not created to make money. (FG2 – S16).

Most instrumental values arose from arguments that defend bees' importance for providing ecological services such as pollination of plants directly related to human nutrition. In some cases, it was said that bees' conservation may lead to less use of agrochemicals in crops, reducing damage to human health. As for eudaemonic values, the only two utterances observed were related to the importance of people losing fear from stingless bees and criticizing the replacement of living beings with technological artifacts. Regarding moral intrinsic values, the human's moral obligation with other species appeared related to distinct ethics, such as egoistic-oriented and physiocentric/cosmocentric-centered statements (Wiegleb, 2002). Lastly, absolute intrinsic values were expressed based on bees' properties, e.g. ecological interactions, such as plant pollination and feeding relationships; bees' evolutionary history and species diversity; ecological balance maintenance.

Instrumental and egoistic-oriented moral intrinsic values were frequently manifested in the early stages of discussion. This spontaneity may occur due to the hegemony of neoliberal ideology, manifested through institutions and social relations and tacitly acquired throughout communicative processes (Bernstein, 2003). Neoliberalism aims to subject social, political, and ecological issues to capitalist market dynamics (Büscher, Sullivan, Neves, Igoe, & Brockington, 2012), which can be detrimental to the environment.

Over time and presenting a conclusive bias, pre-service teachers' arguments shifted towards criticizing instrumental values and manifesting absolute intrinsic and physiocentric/cosmocentric-centered moral values of biodiversity. Since such values often require some scientific knowledge, they are not as spontaneous to the general public as instrumental and egoistic-oriented moral ones (Hunter & Brehm, 2003). Hence, they must have been developed in specialized contexts (Bernstein, 2003). We believe that attending a higher education biology course plays an important role in pre-service teachers' comprehension of intrinsic values of biodiversity. Learning about biodiversity enables students to investigate underlying values, assumptions, worldviews, and interests concerning environmental conflicts, among other abilities (Wals, 1996).

It is a noteworthy fact that eudaemonic values appeared only twice during both focal groups. This may be explained due to the training course's context. In many academic environments, positivism still lingers as a research paradigm. Under such a paradigm, knowledge is objectively developed without the influence of researchers' values (Park, Kong, & Artino, 2019). Therefore, topics such as emotions and religion are not welcome in these environments. Nevertheless, this does not necessarily mean the absence of eudaemonic values in pre-service teachers' discourse in other contexts. Further research would be needed to assess whether such values exist or not.

In conclusion, pre-service teachers manifested a wide array of values of biodiversity, except for eudaemonic values. We believe that scientific education plays an essential role in the acquisition of values of biodiversity, especially moral and absolute intrinsic ones. There is no need to postpone biodiversity learning to higher education; it has to be done since elementary schools. Hence, it is essential to foster high-quality teacher training so that pedagogic practice promotes biodiversity values in children and teenagers. This way, students can construct, critique, emancipate and transform their world (Wals, 1996), contributing to biodiversity conservation and reduction of environmental damage. Questioners and well-informed students can become critical citizens in decision-making regarding the complexity and breadth of environmental issues (Hadjichambis & Reis, 2019). In this context, scientific knowledge emerges as a possibility of unveiling unequal socio-environmental situations. This way, biodiversity education can be considered as a tool for social transformation, a goal of citizen formation, to settle and expand environmental actions in the society. Thus, this study may contribute to educational propositions based on citizen empowerment for more just, ethical, and responsible actions regarding biodiversity issues.

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EXPLORING A SCIENTIST-TEACHER PARTNERSHIP MODEL TO SUPPORT SCIENTISTS' OUTREACH EFFORTS

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The way science is taught in school does not reflect how scientific research proceeds in universities and research institutions. Connecting scientists with K-12 students via creating instructional materials related to current research may help bridge this gap. The purpose of this qualitative case study is to investigate if a scientist-teacher partnership can support scientists in creating a quality lesson plan. Using a Theory of Planned Behavior framework, this study looks at three cases of graduate student scientists and attempts to characterize how they work with K-12 science teachers to develop a lesson plan that can be implemented in the classroom. It also seeks to understand the impacts of this collaboration on the scientists' attitudes and sense of self-efficacy regarding curricular material creation. The study found that scientists and teachers primarily worked together asynchronously, with teachers providing resources and feedback through email. Scientists sought out support primarily at the outset, with teachers helping to brainstorm how the scientists' ideas could be adapted to classrooms and made to fit science standards. They got feedback on their final product at the end of the process. There is evidence that these partnerships contributed to the scientists' self-efficacy and impacted their attitudes toward the behavior, but further research is needed to support this assertion. Implications for best practices for future partnerships are also discussed.

Keywords: Science Communication, Informal Learning, Qualitative methods

INTRODUCTION

The way science is taught in schools — through textbooks and formulaic labs — does not model how scientific research proceeds in universities and research institutions. There is a push to teach science with authentic questions generated from student experiences (Trautmann & Makinster, 2005) and to better understand the nature of science as inquiry (NRC, 2012). One approach is for scientists to participate in the K-12 education system, such as creating classroom materials to introduce students to current, real-world research (Brown et al., 2014). Creating instructional materials is one of the most direct ways to bridge current science with the classroom (Brown et al., 2014 pp. 256-7).

Providing guidance for scientists to do this type of work is essential, as training is crucial to ensure success, especially when the new skill involves domain-specific knowledge (Tricot & Sweller, 2014). Without adequate training and support, scientists risk being frustrated or feeling as if their efforts are inadequate or even wasted (Falloon & Trewern, 2013; Laursen et al., 2007; Simis et al., 2016). Graduate student scientists, in particular, may not have much teaching experience and their formal education rarely includes pedagogy, curriculum development, or how to create engaging classroom activities (Brownell et al., 2013; Gardner et al., 2017; Tanner & Allen, 2006). Existing training programs tend to be time- and/or resource-intensive (Ufnar et al., 2012) and are only available to a small portion of those interested in doing classroom outreach.

Scientist-Teacher Partnerships (STPs) are one way to support scientists who want to engage in K-12 classrooms while also improving science instruction. Historically, when scientists interacted with K-12 teachers and students, they served as a content experts and would visit a classroom to lead one or a few activities; teachers were left to translate the advanced science concepts into grade-appropriate and curriculum-aligned materials (Brown et al., 2014; Falloon & Trewern, 2013). STPs, on the other hand, emphasize *collaboration* and two-way communication between the scientist and teacher that are mutually beneficial to both parties and produce relevant instructional materials. Though the scientist may lead classroom instruction of materials that come out of the STP, the chief emphasis of the partnership is the collaboration itself (Brown et al., 2014; Tanner et al., 2003).

This study looks at how scientists and teachers work together to create instructional materials, specifically a lesson plan in the 5E format (Bybee et al., 2006), and how these interactions affect the scientists' attitudes toward volunteering in schools and their self-perception of their ability to do so successfully. The research questions guiding this study are: (1) How do scientists, specifically STEM (Science, Technology, Engineering, and Mathematics) graduate students, work with K-12 science teachers to develop lesson plans that can be implemented in the classroom? And (2) What do the scientists perceive as the impacts of this collaboration on their attitudes and self-efficacy to successfully create a lesson plan? Findings from this study will provide insight into how teachers can be a resource for scientists looking to develop classroom-ready instructional materials that introduce students to current scientific research.

Theoretical Framework

This research is guided by the Theory of Planned Behavior (TPB) (Figure 1), which posits that behavior can be predicted based on one's intention to engage in an activity, and intention is informed by one's attitudes toward the behavior, subjective norms regarding the behavior, and the perception that one can successfully perform said behavior (Ajzen, 1985).

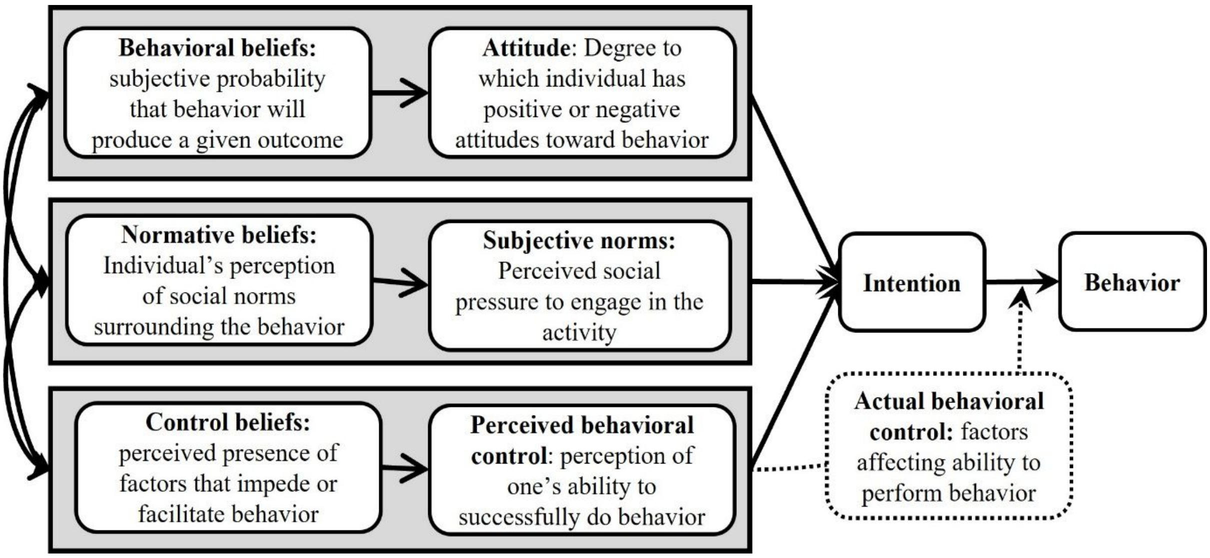

Figure 1. TPB diagram, adapted from Ajzen (2019).

Literature Review

In light of calls to reform K-12 science education, there have been efforts to more directly connect science instruction with current science research. Benefits to teachers of having a scientist in the classroom include increased self-efficacy for understanding and teaching of science (Foster et al., 2010; Gamse et al., 2010; Hamos et al., 2009), increased content knowledge (Foster et al., 2010; Gamse et al., 2010; Ufnar et al., 2017), and a greater willingness to use open-ended, inquiry-based pedagogical approaches when teaching science (Foster et al., 2010; Gamse et al., 2010; Trautmann & Krasny, 2006). There is also research highlighting the benefits to K-12 students, particularly that incorporating hands-on, inquiry-based activities led by scientists fosters excitement about science and increases student engagement (Clark et al., 2016; Foster et al., 2010; Laursen et al., 2007; Ufnar et al., 2012, 2017; Williams, 2002).

The limited research on the impact to scientists of engaging in K-12 classroom outreach shows that it positively impacts scientists' confidence and self-efficacy for teaching undergraduate students and conducting research (Laursen et al., 2007, 2012; Stylinski et al., 2018). It also leads to a better appreciation of the scientists' chosen field (Clark et al., 2016; Laursen et al., 2012; Trautmann & Krasny, 2006) and enhances transferable skills like communication, leadership, and time management (French & Russell, 2002; Gamse et al., 2010; Laursen et al., 2007, 2012; Storksdieck et al., 2017; Williams, 2002). However, there is a lack of research looking at the impacts on scientist participants' attitudes or self-efficacy toward engaging in K-12 classroom outreach.

METHODS

Study Context and Participants

This study employs a qualitative, multiple case study design (Yin, 1994). The context is graduate students in STEM fields who hope to create classroom content for grade school students (kindergarten through 12th grade, approximate ages 5-18) and opt to participate in a scientist-teacher partnership. Participants were recruited from graduate students who took part in an existing two-hour lesson plan development workshop. The workshop was part of a local networking opportunity, The Scientific Research and Education Network (SciREN), which seeks to bring current research and scientists into local classrooms by having scientists create lesson plans highlighting their research.

Interested participants were asked about their previous outreach experiences, including science communication training and formal or informal teaching experience. Three participants were chosen to maximize variation, and each represents a bounded case (Yin, 2009). The participants — Lee, Jessie, and Parker (pseudonyms) —are described in more detail in table 1.

Table 1. Participants' responses to recruitment questions (edited for brevity and to maintain anonymity).

	Lee	*Jessie*	*Parker*
Year in grad school	2nd	3rd	5th
STEM Area	Psychology and Neuroscience	Bioengineering	Pharmacology
Target grade(s) for lesson plan:	K-2, 3-5, 6-8	3-5, 6-8, 9-12	9-12
Experience with K-12 students and/or schools:	In high school: classroom assistant; helped with science demos for elementary school students	[*No response*]	In high school: classroom visits; coaching swimming

Previous trainings or other experience:	Experience in science consulting and writing	None	Science communication 2-day workshop

Data Collection and Analysis

Semi-structured interviews (average length 38 minutes) were conducted with the graduate students following their partnerships. They were transcribed by the first author, de-identified, and returned to participants to review. Feedback was also sought from teachers to triangulate the findings. Interviews were analyzed using the constant comparative method (Corbin & Strauss, 2008). For the first research question regarding how the STEM graduate students and teachers worked together, in vivo coding was used to summarize the data and pattern codes were identified during second cycle coding (Miles et al., 2014). For the second research question, a priori codes relating to the impacts of this collaboration on the graduate students' attitudes, subjective norms, and self-efficacy were developed based on the TPB framework.

FINDINGS

RQ1: Characterizing the Partnerships

The first research question sought to characterize how the graduate students interacted with their teacher partners and what types of support were provided. The pairs primarily interacted asynchronously, sharing lesson plan drafts and feedback via email, though some did have a video call to speed up the collaborative process. As Jessie explained: "it was mostly through email, and she was just giving me advice mostly. We did have, I think, one, Zoom call, just to kind of make things go faster and more efficient. But then after that it was mostly just email communications." The scientists most wanted input at the beginning of the lesson creation process. For example, Lee mentioned that one of her teachers provided "starting points for how to think about approaching the topic in a more problem-oriented way." Jessie similarly sought help getting started:

> There was a lot [of interaction] in the beginning because I didn't really know where to start. I had this kind of nebulous idea about, you know, what I wanted to do with teaching [the topic]. But then, kind of fleshing it out to see which grade levels that would be appropriate for, I think, was the most helpful.

Jessie and Parker also mentioned wanting the teachers' feedback on the final product to learn where they could improve the lesson and if it could be implemented in the classroom and expressed disappointment that they did not receive it.

The three scientists differed on whether they felt they received a good amount of support; Jessie felt that she got enough support throughout the process except at the end, where she would have liked feedback on the final product, whereas Lee wanted more help at the beginning of the process to figure out how her research could be translated to a lesson for younger students. Parker was dissatisfied with the partnership and felt that he did not receive enough support from his teachers overall:

> I pretty quickly got the impression that I wasn't going to get a whole lot out of [the teachers]. And I'm, like I said, I'm super busy myself and, video conferencing, I only try

> to do it when it's mandatory. And if I'm going to be drawing blood from someone I don't, I'm not gonna do that. I'm not going to pull teeth so…

As far as types of support, the teachers provided helpful tools including digital resources, a list of age-appropriate books, and the vocabulary list that students were provided for the course. For instance, Lee's teacher shared a PowerPoint that Lee could use as a model for the activity:

> [The teacher] had this really cool interactive PowerPoint slide that linked out to all of these different smaller links. And [the teacher] was like, 'I could imagine you doing something like this where you like kind of change the hyperlinks and it becomes this kind of like engaging thing where kids can click out and that's fun' which I really appreciated.

All of the scientists expressed the need for guidance on mapping their ideas onto the 5E lesson plan template and how to connect these ideas to a formal curriculum. This was supported by teacher feedback, as several mentioned that the scientists seemed to have a hard time with formalized aspects of teaching including aligning activities to education standards. For example, Jessie's partner teacher noted that Jessie especially sought input on aligning activities to the North Carolina Essential Standards. One of Parker's teachers shared a vocabulary list that he used to find relevant standards. He explained that he was glad not to have to try to understand the standards or navigate their online databases: "I will say, it was great to see that [the vocabulary list] and not have to search through all of the weird standard sites that don't really have keywords set up properly, it seems."

RQ 2: TPB Components

The second research question concerned the Theory of Planned Behavior's three components: attitudes, subjective norms, and behavioral control. Interviews were analyzed to look for indications of the scientists' attitudes toward engaging in classroom outreach and/or participating in a scientist-teacher partnership (STP), to look for the scientists' perception of others' attitudes toward these types of activities, and for references that alluded to whether the scientists felt they could successfully do this type of activity.

The three participants already valued outreach, as evidenced by signing up for the SciREN workshop that preceded the STP opportunity (**Attitudes**). Jessie and Lee indicated positive attitudes toward working with teachers specifically. Jessie mentioned that she appreciated the chance to gain a novel perspective: "I have a couple friends, or I know a couple people who are K-12 teachers, and they talk to me about their jobs and stuff, but, hearing it from kind of a different perspective [was helpful]." In contrast, Parker had more negative attitudes toward the partnership, mentioning that the teachers did not seem interested in helping him develop his lessons, and getting any engagement from them was "like pulling teeth." He indicated that he had low expectations from the outset: "the partnership aspect, it probably met my expectations, but they were low to begin with."

Both Lee and Jessie were involved in their lab group/department's outreach efforts and indicated that doing public engagement was valued by their peers (**Subjective Norms**). When asked about other outreach activities, Jessie spoke of her efforts at the university level: "I already do a lot of intradepartmental outreach, I guess, to undergrads in our department and to other graduate students." Lee is her lab group's 'Outreach Manager' and has engaged with numerous activities across age groups. Furthermore, many of her lab mates were eager to help with the lesson plan development. Lee spoke of an increased recognition of the value of public engagement by others in her department:

> For sure this has been a whisper across the department, and it's been a conversation in my lab, specifically… I don't know if it's been a conversation, but in the kind of small communities that I'm a part of, we have had conversations about how to bring people in and how to also take advantage of the work we do that has meaningful implications for everyday people. And so that's been a conversation about recruitment and outreach and also accessibility.

In contrast, despite being very involved in public engagement himself, Parker felt that scientists generally do not believe that outreach is a good use of their time. This was evidenced when he spoke of himself as "a researcher who's already kind of breaking the rules to do this in the first place" and mentioned, "us scientists, we're not educators." The phrase 'breaking the rules' implies that he feels there is an implicit rule that scientists should not do outreach. By emphasizing that scientists are not educators, it seems that Parker feels that scientists generally do not do this type of behavior, or at least do not do it well.

The scientists initially had reservations about creating a quality lesson plan **(Perceived Behavioral Control**). Jessie spoke of being "scared or intimidated by doing this because I'd never considered myself an educator, really, I don't think that I would be a very good teacher." However, by the end of the partnership, she expressed that she would like to continue working with teachers in some capacity: "I think it was a good experience. I don't know if I… I don't think it's convinced me that I would be a good teacher or anything, but I definitely like thinking about it from that angle […] being a resource for teachers who want to know more about what I do like 'how can I teach this?" It's not clear that the partnership increased her confidence in her ability to create curriculum materials specifically, but it does seem to have impacted her confidence in working with teachers more generally. Lee similarly hoped to continue K-12 outreach and felt that working with a teacher made her lesson plan better. Parker entered into the partnership confident that he could effectively create a lesson plan, saying that feedback from teachers indicating that he was on the right track was not helpful because he "already knew that." He did acknowledge that other scientists might be more in need of such feedback: "I honestly didn't get much more than an 'attaboy!' and a slap on the back. While that, for a lot of people that would be reassuring, for me it was kind of disconcerting."

DISCUSSION AND IMPLICATIONS

The findings from this qualitative case study indicate that when participating in a scientist-teacher partnership, most interaction was virtual and asynchronous (i.e., Zoom video calls and email) and that scientists sought more support when first ideating their lesson plans and when aligning their ideas to formal standard and curricula. This is unsurprising considering that effectively using state or national science standards requires domain-specific skills that are rarely part of a scientist's education (Brown et al., 2014). Working with teachers can help bridge this gap without requiring extra training for the scientists. The teachers also helped connect the scientists' ideas to specific grades levels and subjects, likely due to the breadth and depth of their curricular knowledge and pedagogical experience.

This type of scientist-teacher partnership has the potential to increase scientists' self-efficacy and support their ability to create classroom materials relating to their research. Both Jessie and Lee initially had concerns about their ability to be successful, but both spoke of the partnership as being very helpful for overcoming those concerns. Furthermore, all three participants seemed to think that this type of public engagement activity was worthwhile. However, they did not all seem to perceive that other scientists necesarily felt the same way, as evidenced by some of Parker's statements.

This research supports the notion that STPs can provide effective support for scientists to create classroom materials while still allowing for a minimum time commitment from already overburdened teachers. However, the scientists and teachers both expressed frustration at the lack of structure. Future partnerships would benefit from clear expectations for both parties from the outset. A checklist, suggested timeline, or even concrete deadlines would be helpful for both groups to make sure their expectations are in sync and that they make steady progress. However, the expectations need not be the same for all partnerships; some would benefit from the teacher being involved from the initial stages of ideating activities, as was the case with Lee and Jessie's partnerships, while others may only ask teachers to run through a final version of the lesson, similar to what Parker hoped to gain from the partnerships. Effective partnerships may increase scientists' self-efficacy to do this type of activity, which, according to TPB, may increase their intention to do this activity and eventually their actual behavior. Because this model involves limited financial resources and time from the host organization, it has the potential to be widely implemented to help bridge the gap between scientists and classrooms and potentially help support more authentic science instruction in the future.

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THE MEDIATING ROLE OF SCIENCE LEARNING EXPERIENCES BETWEEN FAMILY SCIENCE CONNECTION AND STUDENTS' SCIENCE CAREER INTENTIONS

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Students' engagement and participation in science have substantial meaning for international development and social justice. Family science connection (or family science capital) has been considered as an important factor which influences students' science intentions. Looking through the theory lens of social cognitive career theory (SCCT), this study supports the hypothesis that students' learning experiences can function as a bridge between family science connection and science career intentions. The findings about the relation between family science connection and learning experiences provide implications for further intervention studies about enhancement of students' science intentions through school learning experiences.

Keywords: science learning experiences, family science connection, science career intention

INTRODUCTION

If students have positive relationships with science and technology, then social, economic and environmental consequences are to be expected (Potvin & Hasni, 2014). However, during school years, numerous students lost their scientific career intentions (Krapp & Prenzel, 2011). PISA has investigated 15-year-old students' career expectations among 72 counties, in which only a quarter of students showed interest in science-related careers (OECD, 2016). In some particular fields of science, the working-class group was notably under-represented (WISE, 2012).

Broadening and increasing students' engagement in science has many substantive meanings. For government, science and technology are regarded as important tools to improve competitiveness (Tytler & Osborne, 2012). In addition, enhancing students' participation in science could contribute to social justice, given that science can provide the under-developed group a route to social mobility (Godec, King & Archer, 2017).

This study focuses on an important factor, family science connection, whose effects on science-related intentions have drawn many researchers' attention (e.g. Hamlyn, Matthews & Shanahan, 2017; ASPIRES, 2013). Specifically, through involving family science connection in a SCCT theory-based model, the mediating effects of learning experiences between family science connection and science career intention are quantitatively represented under the model construct.

The findings of this study can provide suggestions for school science education as well as vocational psychology intervention.

THE THEORY FRAMEWORK: SCCT MODEL

The social cognitive career theory (SCCT) plays a crucial role in vocational psychology research (Tokar et al., 2012). Lent, Brown & Hackett (1994) established the SCCT framework to explain the mechanism of peoples' career intention development by involving person-cognitive factors (e.g., self-efficacy, outcome expectation, and interests) and environmental factors (e.g. family factors, school learning experiences). According to Lent and colleagues (1994), people's self-efficacy and outcome expectation could influence their interest respectively and the interest could further make effects on their career intention. In terms of the delineation of learning experiences in SCCT, Lent et al. (1994) correspond to the idea of Bandura (1986) that learning experiences are the sources to build people's self-efficacy. Specifically, there are four sub-constructs of learning experiences: mastery experiences, vicarious learning, verbal persuasion, and affective state (Lent et al.,1994; Bandura, 1986). This statement has also been supported in empirical research by Pajares and Usher (2009). Additionally, SCCT further considers the paths through which several background contextual affordances influence career choice behaviours (Lent, Hackett & Brown, 2000). Specifically, Lent et al. (2000) state that background contextual affordances can make effects on career intention by directly influencing learning experiences. Consistent with the explanation of background contextual affordances by Lent et al. (2000), family support can be considered as a kind of background contextual affordance, which could influence career intention through the mediation effects of learning experiences (Garriott et al., 2014).

THE CONTENTS OF LEARNING EXPERIENCES

According to Bandura (1986) and Lent et al., (1994), people could develop their self-efficacy by perceptualizing different learning experiences. People could gain sense of capability from mastery experiences, which contributes to their self-efficacy building (Britner & Pajares, 2006). People, especially those who have limited relevant experiences and are uncertain about their ability, can construct their self-efficacy by vicarious learning - observing others conducting tasks (Britner & Pajares, 2006). Positive verbal persuasion including encouragement and empowerment may contribute to self-efficacy beliefs while negative persuasion may undermine self-efficacy. However, in practice, the diminishing effects of negative verbal persuasion tend to be stronger than the enhancing effects of positive verbal persuasion on self-efficacy (Pajares and Usher, 2009). Affective states such as anxiety and stress which are interpreted as negative, contribute to lower self-efficacy (Britner & Pajares, 2006).

AN EFFECTIVE FAMILY FACTOR INFLUENCING SCIENCE CAREER INTENTION: FAMILY SCIENCE CONNECTION

It is evidenced that students' engagement, aspirations, and attainment in science are associated with their familial effects (Archer et al., 2012). For example, Aschbacher, Li, & Roth (2010) state that parents' biased perceptions of science could deprive those students who have initial interests in science from potential science-related trajectories. Although family factors have found to have strong influences on students' science perceptions and career intentions, their relationships are complicated, which are worthy of further investigations (Atherton et al., 2009).

Among studies of numerous family-related factors influencing people's science intention, there are two large scale science education projects observing a family factor termed either family science connection or family science capital. Family science connection represents people's existing science-related resources that are mainly obtained from the family members' attitude and relationship to science (Hamlyn et al., 2017). This kind of science-related resource contains people's family-associated science-related knowledge, interest, experiences and contacts (Archer et al., 2015).

The two projects related to family science connection are shown as follows. The results of the Science Education Tracker project showed that young people with strong family science connections (FSC) were more prone to be keen on science-related careers and to have engaged in more science-related experiences than young people with weak family science connections (Hamlyn et al., 2017). Consistent with this result, in the ASPIRES project, Archer and her colleagues argued that although there was no straightforward causality between family science connection and science aspiration, students from families with high family science connection (she used the term family science capital to denote the science-related resources that a family holds) showed more preference for science-related jobs (Archer, et al., 2015). Archer and her colleagues also did a further in-depth qualitative study to explain the effects of family science connection, which showed that family habitus and privileged science cultural resources collaboratively contributed to people's science preference (Archer, et al., 2012).

RESEARCH AIM AND THE POTENTIAL RESEARCH SIGNIFICANCE

Although family science connection's effects on science career intention have been supported by many previous projects, it is challenging to conduct further interventions for science engagement enhancement based on family science connection. Since family science connection is more likely to be a kind of privileged cultural capital for the middle class (Hamlyn et al., 2017; Archer, et al., 2012), it is difficult to enhance the family science connection in practice, to promote students' science intentions. Fortunately, the delineation of the relationship between learning experiences and family factors in the SCCT model indicates an implication that family science connection may have effects as background affordances on learning experiences and further influence people' s science career choices. If this hypothesis could be supported by empirical studies, future vocational interventions could be conducted aimed at enhancing students' good learning experiences to compensate for students' lack of family science connection. Specifically, based on the sub-factors of learning experiences, future research could provide particular interventions on optimising the school learning context to enhance mastery experience, vicarious learning, verbal persuasion, and positive affective state.

METHODOLOGY

Research design

This study investigates whether family science connection could be involved into the SCCT-based construct. Specifically, the aim is to create a structural model, including students' learning experiences, scientific self-efficacy, enjoyment of science, family science connections and science-related career intentions. The postulated model is illustrated in Figure 1.

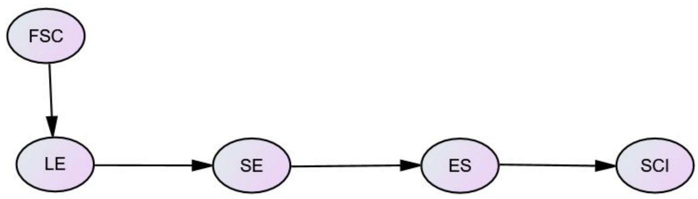

Figure 1. The structure of the postulated model.

NOTE: FSC: family science connection; LE: learning experiences; SE: self-efficacy; ES: enjoyment of science; SCI: science career intention.

Analysis method

To achieve the research aim, the structural equation modelling (SEM) approach is employed. The analysis program employed in this study is Amos 24. Specifically, the approach to structural equation modelling (SEM) in this study involves these two steps (Anderson & Gerbing, 1988).

1. Confirmatory factor analysis (CFA) is employed to test and modify the measurement models.
2. Structural regression (SR) model is created to investigate the structure model of the factors.

Measurement instruments

Only peer-reviewed measurement instruments are employed in this study (as Table 1 shown). To be applicable for the research place China and the targeted high school students, they have been executed some modifications.

Table 1: measurement instruments.

Learning Experiences Questionnaire (Schaub ,2004)	The index of self-efficacy in science (OECD, 2016)	The index of enjoyment of science (OECD, 2016)	Math/Science Intentions and Goals Scale (Smith & Fouad, 1999)	Family Science Connection Index (Hamlyn et al., 2017)

Data sources

There are 1161 high school students (16-18 years old) in China participating this study. Among all the students, there are 491 (42.25%) male students, 669 (57.57%) female students and 1 (0.17%) other. 456 students are from urban schools and 705 students are from rural schools. After checking the missing data and screening the multivariate normality outliers, there are 1155 cases for further model test.

ANALYSIS RESULTS AND FINDINGS

In the SEM research, there are three primary indices which are widely used to assess model fit: the comparative fit index (CFI), the standardized root mean squared residual (SRMR), and the root mean squared error of approximation (RMSEA) (Lent et al., 2018). The model fit may be considered adequate when CFI values are ≥0.90 (Hoyle & Panter, 1995) and preferably, ≥0.95 (Hu & Bentler, 1999); SRMR values are ≤0.08 (Hu & Bentler, 1999); and RMSEA values are ≤0.08 (Browne & Cudeck, 1992) or, more stringently, ≤0.06 (Hu & Bentler, 1999). It is considered that a model can offer a representation of the relations of variables if it meets one or more of these criteria (Lent et al., 2018; Kenny, 2010).

According to Anderson and Gerbing (1988), in practice, there are two steps to test a postulated structural model: A> examination of measurement model by confirmatory factor analysis (CFA) B> examination of regression structural model.

Examination of measurement model by CFA

The results of CFA are shown in Table 2.

Table 2: The model fit indices of postulated measurement model

CFI	RMSEA	SRMR
0.948	0.068	0.057

Although all the goodness of fit indices shown above indicate that the postulated measurement model could converge the data, we should also pay attention to the factor loadings that describe the relations between the observed variables (individual questions) and their corresponding latent variables (factors which will be further investigated in structural model) in each measurement construct (Kline, 2010). The data shows that in the "learning experiences" construct, "affective state" is not significantly correlated with "learning experiences" ($p>0.05$). That implies that the observed variable "affective state" may not be consistent with the learning experiences construct for the Chinese high school participants. In this study, affective state is deleted from learning experiences construct and to distinguish with the previous four-factor construct, the new learning experiences construct containing three sub-factors is termed as "positive learning experiences" (PLE).

Since the measurement questionnaires have been modified to be applicable for the practical situation in China, it is necessary to consider the reliability and validity of the instruments employed in this study. According to Fornell and Larcker (1981), in SEM, the reliability of a single measurement question could be represented by Squared Multiple Correlation (SMC) and the reliability of a measurement model could be represented by composite reliability. SMC>0.4 represents good reliability of a single question and composite reliability>0.7 represents good reliability of a measurement model (Hair et al., 2010). What is more, according to Fornell and Larcker (1981), the Average Variance Extracted index (AVE) could represent convergent validity of a measurement model. If the AVE is less than 0.5, the variance due to measurement error is larger than that due to latent variables. Then both the validity of individual measuring question and the whole measuring model may be bad.

After checking the SMC of all the questions, there are only two questions from the self-efficacy questionnaire that are lower than 0.4. To warrant the reliability of this measurement construct, these two questions are deleted. The composite reliability and convergent validity of each measurement construct are shown in table 3.

Table 3: Composite reliability and convergent validity of every measurement construct.

Measurement construct	Composite reliability	Convergent validity
FSC	0.789	0.556
PLE	0.835	0.627
SE	0.878	0.546
ES	0.947	0.782
SCI	0.862	0.613

NOTE: FSC: family science connection; PLE: positive learning experiences; SE: self-efficacy; ES: enjoyment of science; SCI: science career intention.

The model fit test, reliability test and convergent validity test cooperatively support the proposition that the measurement instruments employed in this study are appropriate for Chinese participants and are suitable for execution of the next step, exploration of a regression structural model.

Examination of regression structural model.

Model fit tests executed on the postulated structural model indicate that this model can converge the data well. The model fit indices are shown in Table 4.

Table 4: The model fit indices of the postulated structural model.

CFI	RMSEA	SRMR
0.945	0.066	0.074

DISCUSSIONS AND IMPLICATIONS

The fitted postulated structural model provides the empirical evidence that family science connection can influence peoples' science career intentions by exerting direct effects on positive learning experiences. Positive learning experiences consist of three factors: mastery experiences, vicarious learning, and verbal persuasion.

Compared with the learning experiences construct with four sub-factors supported by Lent et al. (1994), the positive learning experiences construct with three sub-factors may be more consistent with this study. Actually, the correlations between affective state with the other three sub-factors of learning experiences have also drawn attention of Tokar and his colleagues (2012). Tokar et al. (2012) have investigated the structure of learning experiences questionnaire and found that differentiated from the robust inter-correlations between the other three sub-factors, affective state only had modest correlation with the other three sub-factors respectively. Tokar et al. (2012) tried to explain the inharmonious results of affective state theoretically by the explanation of affective state from Bandura (1986) and Lent et al. (1994). Bandura (1986) states that the nature of affective state is different from the other three types of learning experiences. He (1986) states that affective state is not only a mode of learning but also a response to learning. People may observe their feeling of anxiety when they conduct hard tasks and the observation of personal psychological arousal may be perceived as a kind of learning which teaches them to link the psychological arousal with the specific tasks. Whereas the nature of learning, affective state is still often perceived as a kind of emotion responding to a learning experience, which implies that affective state could be results of the other three sub-factors of learning experiences. In addition, in terms of the items of affective state in the questionnaire, such as "Reading articles about science has made me feel uneasy", they represent students' recollection of the past experience. In accordance with Lent et al. (1994), people's recollection of past experience may be filtered by their affective disposition, especially their recollection of a past affective state. In this sense, the examination of past affective state experience has the risk of being masked by their personal character.

Besides from the explanation based on theory from Bandura (1968) and Lent et al (1994), the source of science anxiety also shed a light on the explanation of this problem. Mallow and Greenburg (1983) state that source of science anxiety may be from some intrusive image of painful memories. However, in the learning experiences construct, mastery experience, vicarious learning, and verbal persuasion are all experiences linked with positive or moderate memories. It implies that students' science anxiety may be more sensitively affected by painful and negative experiences but be hardly influenced by positive and encouraging experiences.

In addition, according to Usher and Pajares (2009), middle school students' affective state is not significantly correlated with mathematics skills self-efficacy and mathematics courses self-efficacy and it is only correlated with mathematics grade self-efficacy. However, in this study, the science self-efficacy questionnaire drawn from PISA is a science skills self-efficacy measure. It is consistent with Usher and Pajares (2009) that affective state is not be involved in a structural model with science skills self-efficacy in this study. Although, statistically, affective state is freed from the learning experiences construct for Chinese high school students, the relevant in-depth qualitative studies are proposed as a focus for future research.

The relation between family science connection and positive learning experiences may shed new light on approaches to enhancing students' science engagement in school education. It also provides implications for the future career intention intervention studies. Specifically, school constructs and activities which could contribute to students' sense of achievement about science are suggested. Corresponding to the importance of vicarious learning, the role models from school, family or society inspire students' aspiration. Insofar as that, the contents related to model-setting are suggested to permeate through science courses and school activities. Finally, the importance of verbal persuasion suggests that more encouragement to students indeed can make effects on engagement. It should be a matter of concern that according to Pajares and Usher (2009), the destructive effects of negative verbal persuasion may be stronger than the constructive effects of positive verbal persuasion. Students probably are more sensitive to depreciating and negatively criticising words. Hence, it is recommended that teachers should be cautious about negative verbal communication with students.

The mediating role of positive learning experiences between family science connection and science career intention may provide an approach to transferring the "task of enhancing students' science participation" from family to schools. Although previous studies constantly reinforce the crucial effects of family science connection on students' science engagement, it seems that if this inspirational research result only piles the task of encouraging students' science engagement on parents, in practice, it is hard to make significant effects. Given family science connection is more likely to be a privileged resource for the middle class (Archer et al., 2012), for families which are not able to gain the conditional socioeconomic resources, the inspirational research result about family science connection appears to be a beautiful but untouchable flower. In addition, the mediating role of positive learning experiences also provides theory rationale for interventions studies that is aimed at enhancing students' science engagement through improving students' positive learning experiences. This implication is especially meaningful for students who have insufficient family science connections.

CONCLUSION

This study investigates the mechanism of the effects of family science connection on science career intention. The findings show that family science connection can be regarded as a kind of background contextual affordance in the SCCT model and positive learning experiences including mastery experiences, vicarious learning and verbal persuasion play a mediating role between family science connection and science career intention. It implies that interventions on learning experiences may be able to compensate for lack of family science connection, to enhance students' science engagement.

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THE ROLE OF PHOTOGRAPHY IN THE PERCEPTION OF ANIMAL WELFARE: A STUDY WITH FUTURE TEACHERS OF PRIMARY SCHOOL

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The role of photography in the perception of animal welfare: a study with pre-service teachers. The present study aims to check the perception of animal welfare in six different situations through the observation of photographs. For that, 194 pre-service primary school teachers (103 Portuguese and 91 Spanish) were inquired. To this end, two versions of the same questionnaire were administered, including for the same situation one photo intended to induce a more positive perception of the welfare of animals. The results of the two versions were compared in terms of the global sample and by country. In general, the animals confined in zoos or bird cages, but where bars were not observed, led to a better perception of the animal welfare. When the photos dealt with a situation about which the respondents had a very critical position, as it was the case of bullfighting, the framing of the photograph had no effect on the perception of animal welfare. The photos where human beings were interacting with animals induced different perceptions, depending on the situations presented. The results allow concluding that photographs can lead to a more or less critical perception of the animals' welfare, with an impact on the assessment of the quality of animals' lives. This conclusion emphasizes the need of a careful selection of the photos in school context, as the ones included in educational resources designed or selected by teachers and in textbooks. Implications of the present results for students of any cycle of schooling are also discussed.

Keywords: Photography, Animal welfare, Teacher training

INTRODUCTION

Animals have always been a source of interest to humans. However, the issue of animal welfare only recently appeared explicitly in the curricula of non-higher education in Portugal and Spain. Thus, the need to work this subject with pre-service teachers is very important due to the following reasons: to help them to be more conscious about the factors that affect animals' quality of life; to help them to better assess the conditions that promote animal welfare, including those related to the health of the ecosystems; to reflect about the impact of different instrumental uses of animals by humans; to develop their skills in the design of activities and resources dealing with the animal welfare issue.

Independently of the approach of the present issue in formal education, the information society broadcasts, through the media, a multiplicity of photos of animals in the most diverse situations and whose observation and analysis allow to perceive whether their welfare is being respected or not. But, as Moutinho (2007) points out, photos do not translate reality, but rather provide a perspective about reality, which allows their use to convey a different set of values and to be at the service of distinct ideologies. Thus, photos reflect the subjectivity of those who take them and are subject to the subjectivity of those who interpret them, and this interpretation can be strongly conditioned and manipulated (Sumozas & Almeida, 2020). Therefore, a photo can enhance a positive animal welfare perception or, on the contrary, promote the opposite idea, even when that does not correspond to reality.

Students of different ages are confronted with photographs involving animals on the internet, in books, in textbooks or in the resources selected or designed by their teachers. These photos can influence students' way of thinking uncritically about the use of animals in the most diverse situations, especially if they are not object of analysis and discussion and, in most situations of daily life, this possibility is difficult to imagine.

The importance of photographs for indoctrination of the perception of reality is not a recent subject, though often forgotten. Hanson (2002) stated that William Hornaday, in 1904, as director of the New York Zoological Park, favoured the following idea: presenting photographs with animals between bars stimulates the negative perception of zoos and makes people feel sorry for their captivity condition. But photos in which the animal appears head erect and properly posed in open spaces makes them forget the condition of captivity of the animals and enhance the perception of welfare.

In this text we present the results of a research from an artistic and constructive perspective, developed between the Polytechnic Institute of Lisbon, Portugal, and the University of Castilla-La Mancha, Spain, focused on the development and use of the artistic photography as a resource for knowledge and reflective analysis of animal welfare. The strategy sought in this work is the analysis of the images by pre-service teachers of both countries, also aiming to verify their ability to construct and elaborate their own interpretation and speeches through the visualization of different images.

METHODOLOGY

The present study involved 103 pre-service Portuguese teachers of primary school, 99 female, and with an average age of 24 years, and 91 Spanish, 57 female, with an average age of 21.3, from two higher education institutions, one from each country.

A questionnaire was designed in two versions involving six situations with animals. Five of them reported situations of instrumental uses of animals by humans (a lion in the zoo, ponies used to transport children, bullfighting, dolphins in captivity, and birds in cages). The sixth situation involved gazelles in their habitat.

In each version, one of the photos intended to give a more positive perception of animal welfare, although the situation surrounding the animals was strictly the same. To emphasize this apparently more positive perception, the following strategies were used: dissimulation of the situation of captivity and the presence of human beings in an empathic relationship with animals, namely children. The most negative perception was given by the presence of confinement bars, harmful actions to the animals by humans and the presence of predators in an ecosystem context.

The photos selected in each version of the questionnaire are presented in Figure 1, with an indication of which ones were selected to induce a more positive or negative perception for each situation.

	A	B	C	D	E	F
	-	+	+	-	-	+
Q1						
Q2						
	+	-	-	+	+	-

Figure 1. The photos present in the two versions of the questionnaire (Q1 and Q2), portraying six different situations (from A to F) for assessing the respondents' perception of animal welfare. It was sought that one of the images would enable a more positive perception (+) and the other one a more negative perception (-) for the same situation.

Thus, 103 respondents (53 from Portugal and 50 from Spain) responded to version A of the questionnaire and 91 (50 from Portugal and 41 from Spain) to version B, randomly chosen. For each situation associated with each photo, it was questioned whether the welfare of the animals was being respected (Yes or No) and why.

Relative frequencies for each situation in each version of the questionnaire were calculated. A chi square test was used to check differences in the animal welfare perception of the participants, comparing the incidence of positive and negative answers in both versions of the questionnaire in each situation. The level of significance considered was $p < 0.05$. The content of the justifications was analysed and is presented concisely due to space limitations.

It is important to explain a few theoretical principles that support the preset methodology, since it was focused especially on visual analysis situated in the context of art-based research methodologies, centred on the ideas of Eliot Eisner. Eisner (1995) considered that the use of forms of thought and representation provided by arts can be research facilitators, highlighting as a good example the possibilities given by photography for reflection about different issues. Within this perspective, one of the methodological research modalities is the A/r/tography, promoted by Irwin (2013) and Marin-Viadel and Rodán (2019), and which unifies artistic actions and research development.

Visual inquiry through photography about human actions is an exercise for helping visualizing the complexity of the world and can be a natural ally in actions and investigative practices (Ramon, 2019). To do this, the concept of visualization implies the development of a complex analytical gaze that embodies our relationship between our personal identity and the environment that surrounds us. It also implies a necessary union between the use of methodological tools with the community and social tendencies of contemporary art, such as “artivism”, an acronym formed by the combination of the words "activist" and "artist", which means "art with an explicit social content ", a good example of which is the approach of animal welfare in art and photography.

In the present methodological approach, it is also important to highlight Benjamin's (2014) concept of "observing", as a tool for analyzing different aspects of the reality, including the way humans observe animals. Thus, the present methodology is based on photography as an analysis tool that involves the artistic drift that allows us to pay attention to the welfare of animals, taking it into consideration in our society. The observation of photographs can facilitate reflection, interpretation and understanding of the situations in which animals are involved.

A great aim of the present study was to seek precisely these aims in pre-service teachers about animal welfare issue, allowing students to create their own discourse about the photos proposed. The comments derived from the photographs thus become an analysis instrument that constitutes an important data collection for the research process.

Working on photographic images and on the ideas they provoke on the viewers allow to involve students in the subject of animal welfare, which is not often approached in teacher training, helping students to assess the quality of life of the different species, especially those that are used instrumentally by humans in different situations.

RESULTS

The results allow concluding that, in general, the respondents' perception about the welfare of animals in different situations was greater when viewing the photos selected to induce a positive perception. However, not all the results corresponded to what was expected. Global results and per country are shown in Table 1.

Table 1. Relative frequency of positive (Y) or negative (N) perceptions of animal welfare in each situation (A to F) considering the global sample and per country, in both versions of the questionnaire (Q1 and Q2). It includes the *p* value obtained by the application of a chi-square test, by comparing the perception of well-being according to the pair of photographs presented for the same situation (see the methodology section).

	A			B			C			D			E			F		
	Y%	N%	*p*	Y%	N%	*p*	Y%	N%	*p*	Y%	N%	*p*	Y%	N%	*p*	Y%	N%	*p*
Global sample																		
Q1	8.7	91.3	0.00	5.8	94.2	0.01	2.9	97.1	0.87	33.0	67.0	0.20	9.7	90.3	0.00	89.3	10.7	0.00
Q2	33.0	67.0		16.5	83.5		3.3	96.7		41.8	58.2		33.0	67.0		68.1	31.9	
	Confirmed			Not confirmed			Not confirmed			Confirmed			Confirmed			Confirmed		
Portuguese sample																		
Q1	7.4	92.6	0.00	9.3	90.7	0.19	1.9	98.1	1.00	44.4	55.6	0.96	7.4	92.6	0.03	92.6	7.4	0.03
Q2	44.0	56.0		18.0	82.0		0	100		44.0	56.0		30.0	70.0		76.0	24.0	
	Confirmed			Not confirmed			Not confirmed			Not confirmed			Confirmed			Confirmed		
Spanish sample																		
Q1	10.2	89.8	0.21	2.0	98.0	0.02	4.1	95.9	0.65	20.4	79.6	0.52	12.2	87.8	0.01	85.7	14.3	0.00
Q2	19.5	80.5		14.6	85.4		7.3	92.7		39.0	61.0		36.6	63.4		58.5	41.5	

Confirmed	Confirmed	Not confirmed	Not confirmed	Confirmed	Confirmed

Thus, the presence of bars in cages that are clearly visible in the frame of the photos where the animals are found, as it happens in two situations of questionnaire 1 (lion and birds), decreased the perception of the animals' welfare. In the case of the lion in the zoo, in the Spanish sample, a statistically significant difference was not obtained between the two versions of the questionnaire, because these students presented more critical justifications regarding zoos, even in the photo in which the perception of well-being was considered to favour the animal. Even so, it was this photo that received a greater number of favourable perceptions.

The presence of human beings in the photos, however, led to different perceptions, a few of them unexpected. In the case of the ponies, the presence of children riding them was perceived as a form of exploitation of the animals, and not as a way to establish a more empathic relationship between animals and children, which could benefit their welfare. Also, the presence of human beings with the dolphins did not significantly change the perception of their welfare. However, the almost identical perception of the situation involving the dolphins in the two photos happened because the participants considered that the tanks in the photo without humans were near the sea and idealized that it would be possible for the animals to make incursions in the ocean and return. In the case of bullfighting, the photos did not motivate changes in the perception of the students, who proved to be very critical of this show considering it very cruel to animals, and despite being a show rooted in the Spanish and Portuguese cultures. Finally, the presence of a feline in one of the photos with gazelles led to a different perception in the welfare of these animals, although the predator in the image did not appear to show any particular interest for its potential prey.

DISCUSSION AND CONCLUSIONS

The present study shows how photos can influence the perception of reality and lead the subjects to interpret a certain context as being more or less positive in terms of animal welfare. However, in situations where the respondents' critical opinion was stronger, as it was the case of bullfighting, the photos did not affect the perception, a dimension that needs further research. The presence of human beings in interaction with animals was not always perceived in the same way, an aspect that also deserves further research.

Even so, this pioneer study shows how the selection of photos during the teaching practice is important for the perception of students about the welfare of animals in different situations. This selection can also be used to develop their critical thinking about the use of animals by humans, namely in the way of looking at situations that involve captivity. It is therefore considered important to extend the present study in the future to students of different schooling cycles, in order to assess the power of photos in the perception of animal welfare. Finally, it seems relevant to highlight the importance of the present issue in teacher training, relating it to the need of developing the critical thinking of all students, regardless of their age.

With the present study it was possible to verify possibilities of a successful connection between the fields of Environmental Education and Artistic Education, through the incorporation of methods and tools such as photography, which functioned as a stimulus for the identification of pupils' perception about animal welfare, showing animals in different situations. It also opens other opportunities for future interdisciplinary research in the field of animal welfare or other environmental issues, helping teachers to become more conscious about their didactic options, due to the implications of the results in the children's perceptions about animal welfare.

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COVIEWING AND INTERTEXTUALITY IN THE USE OF VIDEOS IN CHEMISTRY CLASSES

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The aim of this study was to identify what strategies chemistry teachers adopted to relate the teaching objectives and the films and videos shown in class to motivate the students' interest in the discussion and learning of Chemistry. The participants were three teachers and their students in a public high school. The data were produced from the analysis of the videos displayed, observation of the teachers' actions during the classes, and interviews with them. Teaching actions generally had a regulatory effect and sought to control the students' understanding and participation. Coviewing and intertextuality were the main strategies adopted by teachers. These strategies helped students to put themselves in the position of seeing the videos in order to learn, and to accept the videos concerned the teaching-learning processes. According to these results, the motivation to learn science was not automatic and depended on the strategies adopted to insert the videos in the classes.

Keywords: Multimedia and Hypermedia Learning, Teaching Practices, Video Analysis.

INTRODUCTION

The research literature on video use in Science Education has affirmed the motivating and facilitating character of learning of this resource (Frey, Mikasen, Griep, 2012; Cajigal *et al.,* 2014; Yerrick, Simons, 2017). There is also a constant concern to justify the use of audiovisual as valid and necessary to teach science (Rezende *et al*., 2015). However, the literature has not found answers related to how this motivation or learning facilitation is obtained, nor on which factors interfere with audiovisual teaching-learning. This leads us to consider that researches assume these potentialities of motivation and facilitation of learning are inherent to audiovisual. We disagree with this understanding, because the display of videos in teaching can also provoke resistance that leads, precisely, to the demotivation of students. In this context, teachers seem to be the central actors in the construction of the conditions and contexts of showing videos to teach science, because their actions turn to the need to insert and adapt the audiovisual to classes, so that it is related to teaching. We call this process of adaptation and appropriation "audiovisual readdressing" (Rezende *et al*., 2015). The readdressing results in new contexts for the presentation of the works, contexts that stimulate new reading goals related to the teacher's curriculum and teaching objectives. The teacher's mediation when showing audiovisual has been shown, therefore, to be a fundamental aspect of this practice. We present below the results of a research on the readdressing of audiovisual materials in Chemistry classes. We assume that films and videos are always addressed (Ellsworth, 1997), and their use for educational purposes potentially involves some kind of adaptation.

When readdressing videos or films, the teacher performs actions that interfere with the reception and the way of reading them. This mediation, therefore, is an action that can affect not only the meaning, but also the way in which information is presented, the story is narrated, or the characters represented, among other aspects. Thus, when showing a commercial film, for example, the teacher may be interested in showing certain aspects that his students would not give relevance in another context.

Readdressing thus implies building a specific context to (re)watch a film in the classroom, considering educational purposes such as identifying, understanding or deepening the scientific concepts more or less evident in the film. Therefore, the concept of readdressing aims to specifically study the displacements of spectatorship produced by the teaching-learning situation as conditions for this situation.

Based on this understanding, we formulated this study guided by the following question: how do chemistry teachers integrate films and videos into their classes to make students understand them as learning resources and thus motivate them to learn science? The aim of this study was to identify what audiovisual readdressing strategies they adopt to relate teaching objectives and audiovisual materials and to motivate students' interest in the discussion and learning of chemical concepts.

METHODS

As the main theoretical framework, we used the concepts of modes of address and readdressing. We started from the premise that films and videos are always addressed (Ellsworth, 1997), and that their use for educational purposes implies adaptation. Readdressing is a new address produced from the conditions built by the teacher to display a film and taking into account its original address. Other concepts were included throughout the analysis, such as coviewing and intertextuality. According to Kirkorian, Wartella & Anderson (2008) *coviewing* is observed when, for example, children watch television programs in the company of a mediator (parents, siblings, guardians). These, through comments on what is seen, can control, stimulate and monitor the child's production of meaning. *Intertextuality* is defined as the insertion of other texts, audiovisual or not, to be read in the light of each other, thus potentially modulating their meanings (Werner, 2004).

The methodology of this study is organized according to the articulation of several stages and instruments, also considering the necessary articulation between the data produced. Thus, in order to achieve the main objective of the studies, it was necessary to describe the classes with video and the actions taken to adapt the selected material to achieve the teaching objectives. As a result of this procedure, and in a complementary way to it, it was necessary to analyze the specificities of the chosen films and videos, identify the teaching objectives of the teachers and, to some extent, the knowledge they mobilized to build the readdressing. The survey was designed in this way in order to generate enough data for the readdressing analysis.

The participants of this study were three teachers and three classes of students (50 students in total) of Chemistry of a public high school in Rio de Janeiro (Brazil). This school was chosen because it met the following criteria: to offer the necessary conditions for the use of audiovisuals, and to have a teaching staff with experience and solid disciplinary background. Teachers were selected through questionnaires that identified the frequency and type of use of audiovisual in the teaching of Chemistry. The participating students were those present in the observed classes.

The data produced came from the analysis of the videos displayed, observation of the participating teachers' actions during the classes in which they displayed videos, and individual in-depth interviews with the teachers.

Data collection was done through notes in a field diary and voice recordings of teachers during classes and interviews. The recordings and interviews were transcribed and, as well as all the documentary material, were analyzed using a specific instrument of analysis developed by the authors. The videos shown in class were analyzed so that fundamental elements of their original address were identified, such as objectives, preferential meaning, content, language and aesthetic elements that would allow assessing which audience is potentially included or excluded as a preferential audience, that is, their address (Ellsworth, 1997). This information is important to analyze how the address is modified or not through readdressing strategies. In addition, the identification of elements that characterize the address is a central procedure to understand how these elements are displaced or highlighted, what emerges or disappears and what must be inserted by the teacher in his proposal for the student to see the film from a certain point of view and with a specific objective. Such aspects were considered as part of the construction of a specific "spectator place" from where the student should see the work in order to learn.

The observation of classes was adopted as a procedure because it would allow us to describe the teachers' actions when showing videos and identify those that were related to readdressing. From the observation we obtained data on what exactly teachers do to adapt the video(s) to their classes. These data refer to any and all teachers' actions concerning the video(s), such as interruptions, explanations, and notes. They also turned to those actions that referred directly to the "public", that is, to the students. With this information, we analyzed how audiovisual was inserted in the classes (with what objectives, what functions were assigned to them, etc.), as well as which care was taken to adapt them to the class (explanations, cuts, editions, etc.) and to the teaching objectives.

The interviews, in turn, helped us to identify the reasons why the teachers decided to adopt the procedures and cautions effectively adopted during the class, in addition to deepening the questioning about aspects of the class that were not clear during the observation. We also requested access to the participating teachers' planning, contents, class objectives and, mostly, to the audiovisual materials that would be used. These materials were analyzed prior to the observation of their exhibition in class with French Film Analyses (Vanoye & Goliot-Lété, 1993).

RESULTS

In the first class observed, the teacher used an audiovisual report that focused the controversy about the construction of a hydroelectric power plant. The students watched in *coviewing* with the teacher and, later, she inserted some concepts of Chemistry that were not part of the video, through the reading of a printed text (intertextuality). In the debate after the video was presented, the teacher sought to control the meanings produced by the students. We observed resistance on the part of the students to the reading of the teacher, since they positioned themselves in a convergent sense to the meaning conceived by the producers of the report, and not to that defended by the teacher.

The discussion after the video generated a dispute over its meanings. In general, the students were in agreement with the perspective adopted by the reportage. However, throughout the debate, the teacher negotiated the meanings that she initially defended, and reconsidered her position in the face of some students' objections, sometimes converging with their reading. The readdressing strategies made by the teacher were aimed both at the insertion of scientific concepts (intertextuality) and at coviewing, in this case in a clear attempt to control the students' reading, even without success. There was, therefore, a prevalence of the preferred meaning of the video over the teacher's coviewing. The interaction between the teacher and the students built new readings of the materials used, despite the attempt to control the students' readings.

In the second observation, the teacher exhibited the American feature film *Erin Brockovich*. She chose this film because there was a specific scene about the relationship between oxidation number and water contamination. The teacher aimed to relate the socio-environmental problem focused in the film to the recent ruptures of mining waste dams in Brazil. In the classes, the reading of journalistic reports (intertextuality) after the screening of the film in two parts aimed to direct students to relate the dam ruptures and chemistry content, through the example presented in the narrative of the film. The analysis of the film indicated that its preferred meaning addressed questions about, for example, female empowerment and citizen action, and not exactly concepts of Chemistry. Nevertheless, the teacher used strategies such as scene repetition, *coviewing* and intertextuality to direct students' readings to the relations between chemistry and environmental pollution. The readdressing actions evidence the teacher's intention to provoke a spectatorial shift: from a common spectator to a Chemistry student. This shift seems to have occurred, since the meanings established by the students corresponded to the teacher's intertextual referral, albeit within certain limits. The dominant understanding of the students followed the teacher's orientations.

In the last class observed, the teacher exhibited a set of videos whose contents converged to an expanded discussion about organic functions and illicit drugs. The teacher's motivation to show these videos lies primarily in their recognition of correct and quality content. But the teacher identified in these videos not only relationships with the content of the Chemistry class, but also their suitability for the age group, the level of knowledge or maturity for discussion and some of the students' tastes, needs and interests.

Despite being didactic videos, the teacher made edits to adjust its duration to the available class time and inserted conceptual information through his speech (coviewing) and slides (intertextuality). These modifications of the videos were subtle, but necessary to insert them in the reading path the teacher wanted to reinforce. Thus, the main readdressing strategy was coviewing. Coviewing occurred when the teacher shared information before and during the video, and orally guided students. He prepared students to view images with human organs and emphasized what they should observe and understand from the videos. Thus, it is presumable that the action of preparing to view human organs was done with the intention of reducing resistance to the video content, as well as the sharing of information during the exhibition to reduce difficulties of understanding or biases. These statements aimed to reduce both possible resistance to the visualization of the images, as well as questions and misunderstandings. In addition, the strategy of using slides and the insertion of complementary and conceptual information between the videos (intertextuality) were also strategies of readdressing, which, as well as coviewing, contributed to the effectuation of the student's displacement to the position of "apprentices of Chemistry", and not just "curious spectators".

DISCUSSION AND CONCLUSIONS

In this research, two main strategies of readdressing were found: coviewing and intertextuality. Coviewing proved to be a strong readdressing strategy in the observed classes. The main mark of coviewing in this research is the teacher's speech before, during or after the videos are shown. Among its functions, we found to direct and modify the meanings produced by the students (control of the polysemy of readings), reduce resistance to the characteristics of the videos, and draw the attention of the students to certain aspects of what was displayed.

Intertextuality, on the other hand, was also frequently adopted in the classroom. The functions of intertextuality were to promote associations of meanings between the texts used (and not only of the videos); direct students to the objectives of the class, avoiding dispersions brought by the videos; and "didatize" the videos, encouraging them to be read "in the light" of each other, and not randomly.

Thus, readdressing actions generally had a regulatory effect, which sought to control the students' understanding and participation. Among its results, we may notice that the students' readings were more directed to the objectives of the class, and that there was, in general, recognition by the students of the appropriate pedagogical use of films and videos, as relevant and appropriate teaching materials for the classes. Coviewing and intertextuality strategies, among others, such as edits, cuts and different forms of exhibition, aimed at objectives such as preparing to watch the video, complementing and "didacticizing" the content, approaching the students' universe (in a kind of contextualization), and the control or reduction of resistances.

Thus, coviewing and intertextuality collaborated so that the students, as spectators, placed themselves in the position of seeing what was exhibited in order to learn (Odin, 2000), and to accept that the videos concerned the teaching-learning processes in which they participated. The construction of this position can be noted when students were encouraged to put the expectations of entertainment they could have in the background, and to devote themselves to occupy the position of "science learners", as in the class with the film *Erin Brockovich*, or when students watched videos about illicit drugs to "learn Chemistry", and not just for an individual curiosity. On the other hand, they also reinforced a position of study in front of the videos, directing their reading and understanding to objectives related to the discipline and the subject taught. Therefore, the actions performed by the teachers, when showing films and videos in class, were directed to create a context that made the students understand that the materials displayed concerned the contents and objectives of the class, and therefore were of interest to their learning. Thus, the motivation to learn science came from the set of activities in which the video was included, and not from it alone.

In relation to literature, this research allowed us to question how much one can actually assume that the exhibition of films and videos in science teaching is automatic and necessarily motivating. As we have seen, depending on factors such as the type of audiovisual, its duration, the activity in which it is inserted and the mediation of the teacher, the exhibition can provoke resistance that leads, paradoxically, to the failure of the activity and, precisely, to the demotivation of the student.

Likewise, no matter how much readdressing strategies try to build a fixed, coherent and inclusive position for the students, having a regulatory effect, the students, in general, have kept their autonomy in the production of new meanings. Thus, to be motivated to teach with audiovisual, students first needed to realize that this material concerns them, and also concerns the teaching-learning processes in which they participate. This audiovisual potential seems to depend on the strategies adopted by teachers to insert audiovisual in the class.

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EFFECTS OF DOING HOME EXPERIMENTS WITHIN A CHEMISTRY CITIZEN SCIENCE PROJECT

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Citizen science has become increasingly popular in many areas of research, in particular in biodiversity, ecological and environmental sciences. In addition to its scientific potential, many citizen science projects aim to promote citizens' education and sensitivity to environmental issues. In an ongoing chemistry citizen science project in Northern Germany, in which citizens monitor nitrate values in local waters, educational aspects are supposed to be fostered by conducting home experiments. In an accompanying study, the effects, such as an interest in science and nature, self-efficacy for environmental action concerning the nitrogen problem and scientific enquiry skills, are being assessed. The initial results show slightly positive effects that are irrespective of gender or age. To gain deeper insights into the potential of home experiments in connection with citizen science projects, qualitative interviews, based on the initial findings that are presented in this study, will be conducted.

Keywords: Society and Environmental Education, Informal Learning Environments, Self-efficacy

INTRODUCTION

Citizen science, in which members of the public actively participate in scientific research, can be traced back hundreds of years. It has paved the way for our current understanding of nature and the environment to a significant extent (Miller-Rushing, Primack, & Bonney, 2012). In recent years, citizen science has experienced an enormous growth and also change, proving its potential, not only for collecting scientific data but also for fostering educational aspects and environmental awareness of participating citizens (Brouwer, van der Wielen, Schriks, Claassen, & Frijns, 2018; Conrad & Hilchey, 2011).

Several studies have examined participant learning outcomes in citizen science projects, and have shown that participating in such projects can have a positive impact (Hiller & Kitsantas, 2014; Peter, Diekötter, & Kremer, 2019). There are also studies that reveal no significant change in aspects such as attitude, scientific knowledge and understanding or scientific skills (Brossard, Lewenstein, & Bonney, 2005), which leads to the question of how citizens can be further supported in their learning process. This support can vary, depending on the anticipated learning outcomes as well as the number and location of the participants. Although various supporting opportunities have been reported, including interactive, digital platforms (Herodotou, Aristeidou, Sharples, & Scanlon, 2018), training programmes (Cronje, Rohlinger, Crall, & Newman, 2011), accompanying reading material and the performance of experiments to gain deeper scientific insights (Kruse, Kiessling, Knickmeier, Thiel, & Parchmann, 2020), little research has been conducted on the effectiveness of these actions.

To address this research gap, a citizen science project has been designed and is being carried out in Northwest Germany (Brockhage, Lüsse, Pietzner, & Beeken, 2021). In this project, students and citizens conduct research together with scientists on the nitrogen pollution of local waters. Around 200 students have been trained in different ways to become experts, for example in student laboratories and online seminars, which enables them to support the allocated citizens. Most of the 600 participating citizens have received material to fundamentally elaborate on the topic. The focus of our study, however, lies on around 100 citizens who received optional training through the so called 'Nitrogen Box'. This box contains an experimental kit with information material and home experiments that allows these citizens to gain a deeper understanding of the topic, including an understanding of the nitrogen cycle and an investigation of fertilizers and legal bases, for example. In a school setting, home experiments have already been successfully implemented, albeit in the field of electrochemistry, and were perceived positively by the participants (De Vries, Martin, & Paschmann, 2006). In the context of citizen science, the potential of home experiments has not yet been investigated. An exploration of the following research questions should help to close this research gap:

1. How are the content and the handling of the Nitrogen Box perceived by citizens?
2. What impact does the use of the Nitrogen Box have with respect to interest in science and nature, self-efficacy for environmental action concerning the nitrogen problem and scientific enquiry skills?
3. How do interest, self-efficacy, scientific enquiry skills and perceptions of the content and handling of the Nitrogen Box differ with respect to the gender, age and educational level of the citizens?

CITIZEN SCIENCE AND SCIENCE EDUCATION

Citizen science, also referred to as public participation in scientific research (Bonney, Ballard, et al., 2009) or community-based environmental monitoring (Conrad & Hilchey, 2011) describes the participation of non-professionals in authentic scientific research, in partnership with professional scientists and institutions (Dickinson et al., 2012). The degree of participation, however, can vary and is categorised into different project types. In contributory projects, the project structure and goals are defined by researchers and the public is primarily involved in data collection. In collaborative projects, citizens not only collect data but also help in other parts of the project, such as data analysis and the dissemination of findings. In co-created citizen science projects, at least some, if not all, citizens get involved in almost all aspects of the research process (West & Pateman, 2017).

Many citizen science projects do not only focus on the collection of scientific data but also, or even mainly, pay attention to citizen education (Jollymore, Haines, Satterfield, & Johnson, 2017; Kelemen-Finan, Scheuch, & Winter, 2018). In Europe, educational objectives are pursued by the COST Action CA15212 'Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe' (COST Association, 2016; Roche et al., 2020). According to PISA 2006, scientific literacy is characterised by 'scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues', by 'understanding of the characteristic features of science as a form of human knowledge and enquiry', by the individual's reflective behaviour and 'willingness to engage with science-related issues and with the ideas of science' as well as the 'awareness of how science and technology shape our material, intellectual, and cultural environments' (OECD, 2006). Scientific literacy does not only address knowledge about science and the environment but also comprises how individuals respond to scientific and environmental issues, which can be reflected in the interest for science, scientific enquiry and a willingness to take on responsibility for sustainable development (Bybee, 2008; OECD, 2006). The attainment of scientific literacy aims to enable learners to actively participate in socio-scientific issues, socio-political action and dialogical processes concerning science-related and environmental issues (Liu, 2013; Santos, 2009). The potential of citizen science in this context has already been outlined by Bonney, Cooper, et al. (2009). However, these researchers identified the measurement of the improvement in the participants' scientific literacy as being challenging. By reviewing citizen science projects investigating educational impacts, Bonney, Ballard, et al. (2009) developed four categories to set the first steps towards assessing the project impact. The categories are 1) awareness, knowledge and/or understanding, 2) engagement or interest, 3) skills and 4) attitudes and behaviours. Phillips, Porticella, Constas, and Bonney (2018) continued this work by extensively examining the learning outcomes in citizen science, based on other studies in the field of informal science education as well as on survey data of citizen science projects, to develop a framework to describe and evaluate learning outcomes (Table 1).

Table 1: Framework for articulating and measuring individual learning outcomes from participating in citizen science, according to Phillips et al., 2018

Learning outcome	Description
Interest	The degree to which an individual assigns personal relevance to a scientific or environmental topic or endeavour
Self-efficacy	The extent to which a learner has confidence in their ability to participate in a scientific or environmental activity
Motivation	The goal-driven inclination to achieve a scientific or environmental behaviour or activity
Content, process and nature of scientific knowledge	Knowledge of scientific content and the nature of science; understanding of the scientific process and how science is conducted
Skills of scientific enquiry	Procedural skills, such as asking questions, designing studies, collecting, analysing and interpreting data, experimenting, reasoning, synthesising, using technology, communicating and critical thinking
Behaviour and stewardship	Measurable actions resulting from engagement in citizen science, such as place-based and global stewardship, new participation and community or civic action

HOME EXPERIMENTS IN CHEMISTRY TEACHING

Using home experiments, also known as kitchen chemistry, to supplement or even replace laboratory experiments has mainly been tested and evaluated in higher education institutions, such as universities, in particular in the context of distance education (Kennepohl, 2007; Lyall & Patti, 2010). The closure of campuses in 2020 and 2021, due to the COVID-19 pandemic, has intensified the need for alternative distance learning opportunities in chemistry education in both schools and universities (Domenici, 2020; Schultz, Callahan, & Miltiadous, 2020). A descriptive study by Sari, Sinaga, Hernani, and Solfarina (2020) in this context has shown that to perform home experiments, easily accessible materials that are already available at home are preferred. However, it is occasionally necessary to purchase special chemicals and materials or to create virtual laboratories. The effectiveness of virtual laboratories in comparison to hands-on laboratories is relatively unexplored so far (Domenici, 2020). The effect of home experiments in 7th grade, however, has been explored by Gendjova (2007), showing that the use of home experiments can increase pupils' interest in, knowledge of and satisfaction with chemistry. These positive effects may account for the connection of chemistry to contexts that are relevant to life. In such contexts, pupils are encouraged to design their own investigations, which is an essential part of fostering their decision-making competences (Gendjova, 2007; Yip et al., 2012). In citizen science contexts, the use of home experiments has not yet been investigated. Nevertheless, possibilities for further citizen involvement in learning and research processes are of research interest (Oliveira, Jun, & Reinecke, 2017). Designing suitable home experiments in citizen science contexts can be particularly challenging, in particular when they concern the fundamental questions that were formulated by Lyall and Patti (2010): 'Who is the target audience?', 'What is the purpose of the experiments?' and 'What are the expected outcomes?'. In comparison to formal education contexts, prior knowledge and experience of participating citizens can be unknown and, above all, extremely diverse.

THE NITROGEN BOX

Through anthropological processes, mainly in food and energy production, the release of reactive nitrogen compounds has increased globally, which causes multiple effects in the atmosphere and in ecosystems and has effects on human health (Galloway et al., 2003). In Germany in particular, surplus reactive nitrogen is considered to be an environmental challenge that results in consequences such as biodiversity loss, reduced groundwater quality and possible effects on human health (Salomon et al., 2016). Governmental approaches to tackle these issues have not yet achieved the desired improvement and conflicting interests of different stakeholders further increase the complexity of this problem (Kastens & Newig, 2007; Kirschke, Häger, Kirschke, & Völker, 2019).

The intention of the Nitrogen Box is to pass on information in a simple, understandable and comprehensive way, enabling citizens to critically reflect on the media presentation of the topic as well as on their own behaviour and attitudes. As shown in Figure 1, the box contains two booklets, equipment, and chemicals. One booklet contains information and answers to questions such as how nitrogen is released and distributed in the environment, what consequences are to be expected when too much reactive nitrogen is released, which laws exist on this topic, how water can be kept clean and how every individual can contribute to environmental protection. Instructions for 15 suitable home experiments that are related to these topics are described in a second booklet:

1. Testing water samples for ammonium ions
2. Testing water samples for nitrate ions
3. Examining the root nodules of legumes
4. Urea decomposition in soil
5. Nitrogen oxides in waste gases
6. Adsorption of ammonium and nitrate ions in soil
7. The effect of urea on soil
8. Investigating the nitrate levels of fruit and vegetables
9. Nitrate and nitrite in spinach
10. Nitrate levels in pickled meat
11. Colour development in pickled meat
12. The effects of different nitrogen inputs on plant growth using cress as an example
13. Determining the nitrogen content in soil
14. Soil nitrogen mineralisation
15. Nitrate removal by means of ion exchange

Figure 1: The Nitrogen Box

All experiments can easily be conducted at home with the aid of the included equipment, chemicals, and general household products such as a funnel, spoons, and jars.

METHOD

A first version of the Nitrogen Box was made available to 13 schools that are participating in the citizen science project. Teachers' feedback after using the box with their pupils was used to improve the box for citizens. Thereafter, out of approximately 630 citizens who are taking part in the citizen science project by regularly measuring nitrate values of a self-chosen water body, around 100 citizens had the opportunity to sign up for the Nitrogen Box. They received the experimental kits by post in August and September 2020, including a four-sided post-questionnaire to evaluate the potential effects of the home experiments. A post-questionnaire only (instead of both a pre-questionnaire and a post-questionnaire) was used since a much lower response rate was expected for combined pre- and post-testing. Therefore, prior validated scales by the Cornell Lab of Ornithology were adapted and translated to evaluate specific targeted learning outcomes. The 12-item 'interest in science and nature' scale (Phillips, Porticella, Bonney, & Grack-Nelson, 2015), the 8-item 'self-efficacy for environmental action' scale (Porticella, Phillips, & Bonney, 2017) as well as the 12-item 'skills for science inquiry' scale (Phillips, Porticella, & Bonney, 2017) were used. All scales were 5-response Likert scales, ranging from 1 for strong agreement to 5 for strong disagreement. Additionally, the citizens were asked to rate the quality, content, and handling of the Nitrogen Box for 12 items related to the included brochure and the experiments, using the same 5-response Likert scale.

RESULTS

In total, 97 citizens received the Nitrogen Box and 36 citizens (25 males, 10 females, 1 N/A), aged between 17 and 83 years, completed the questionnaire. For data analysis, IBM SPSS statistics 27 was used. Regarding the content and handling of the Nitrogen Box, a mean value of 1.75 (SD = 0.51) on a scale ranging from 1 for positive perception to 5 for negative perception was calculated. For the evaluation of the possible impacts of the Nitrogen Box regarding learning outcomes, descriptive statistics were used as well. Interest in science and nature has been rated with a mean value of 2.62 (SD = 0.88), self-efficacy for environmental action concerning the nitrogen problem with a mean value of 2.84 (SD = 0.55) and scientific enquiry skills with a mean value of 2.16 (SD = 0.61), on a scale ranging from 1 for strong impact to 5 for no impact. Mann-Whitney U tests were used to evaluate the possible effects of gender, age, and educational level on the perceptions of the Nitrogen Box, as well as on learning outcomes. As shown in Table 2, no significant differences regarding gender were found.

Table 2: Effect of gender on perceptions of the Nitrogen Box and on learning outcomes.

Factor	Gender	M_{Rank}	U	Z	p
Perception of the Nitrogen Box	Male	19.76	81.000	-1.609	0.113
	Female	13.60			
Interest in science and nature	Male	17.60	93.500	-0.586	0.564
	Female	15.39			
Self-efficacy for environmental action	Male	16.05	83.000	-0.524	0.625
	Female	14.22			
Scientific enquiry	Male	16.86	80.000	-0.829	0.428
	Female	13.89			

To evaluate the possible impacts of age, the sample was divided into two age groups, with half the sample aged between 17 and 51 years old and the other half between 52 and 81 years old. Mann-Whitney U tests showed no significant effects regarding age (Table 3).

Table 3: The effect of age on the perception of the Nitrogen Box and on learning outcomes.

Factor	Age (years)	M_{Rank}	U	Z	p
Perception of the Nitrogen Box	17-51	16.71	131.000	-0.466	0.658
	52-81	18.29			
Interest in science and nature	17-51	16.53	127.000	-0.019	1.000
	52-81	16.47			
Self-efficacy for environmental action	17-51	15.91	89.500	-0.641	0.531
	52-81	13.88			
Scientific enquiry	17-51	16.03	101.500	-0.377	0.711

52-81	14.81

The only statistically significant difference was found for the perceptions of the content and handling of the Nitrogen Box between citizens with academic degrees ($M_{Rank} = 13.02$) and those without an academic background, as shown in Table 4 ($M_{Rank} = 24.95$; $U = 33.500$, $Z = -3.364$, $p < 0.001$, $r = -0.58$).

Table 4: The effect of academic background on the perceptions of the Nitrogen Box and on learning outcomes.

Factor	Academic degree	M_{Rank}	U	Z	p
Perception of the Nitrogen Box	Yes	13.02	33.500	-3.346	< 0.001
	No	24.95			
Interest in science and nature	Yes	17.26	78.500	-1.121	0.268
	No	13.35			
Self-efficacy for environmental action	Yes	14.63	83.000	-0.124	0.923
	No	14.22			
Scientific enquiry	Yes	14.63	82.500	-0.354	0.729
	No	15.83			

DISCUSSION AND OUTLOOK

The results show that the use of the Nitrogen Box in the context of a chemistry citizen science project tends to have slightly positive effects on the participating citizens' interest in science and nature and on the self-efficacy of citizens to engage in environmental action concerning the nitrogen problem. A greater positive effect can be identified regarding scientific enquiry skills. The minor increase in the interest in science and nature may be due to the assumption that many citizens were already very interested in the topic before using the box, which might not have left much room for further enhancement. However, because of the low number of participants, the study was limited in delivering representative results.

Overall, more men than women participated in the study, which is a typical phenomenon in citizen science projects (Price & Lee, 2013) and one that should be further investigated. Significantly more positive perceptions could be seen among citizens with an academic background than among those without an academic background. This could be caused by the extent and complexity of the material in the box. On the one hand, the Nitrogen Box was designed to be as simple and as understandable as possible but, on the other hand, the content and tasks were made to challenge the citizens and encourage them not only to think critically but also to support their creativity and decision-making abilities with regard to conducting the experiments (Yip et al., 2012). Therefore, simple straightforward tasks and experiments were included as well as more difficult tasks and experiments and longer experiments.

When using experimental kits in a citizen science context in the future, even more attention should be paid to the design of the material and the experiments. Possible opportunities include more and clearly marked differentiation and learning support. Another option would be to reduce the overall scope of the material and the number of experiments. However, although the experimental kit would be overstretching some participants less, it would possibly be too simple for others.

Therefore, to gain a deeper understanding, qualitative interviews with some of the participants have been conducted and will be evaluated in the context of future research. It is expected that through these interviews, information regarding the added value of experimental kits in citizen science contexts can be obtained. Additionally, these interviews may lead to recommendations for future citizen science projects about the way in which such experimental kits should be created, as far as scope and complexity are concerned.

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NAVIGATING MICRO AND MACRO LEVELS OF AGENT-BASED SIMULATIONS TO BUILD ANALOGIES WITH REAL-WORLD ISSUES

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Agent-based simulations are important tools not only for scientists and experts but also for policymakers and citizens that are called to make decisions on these issues. However, simulations are complex tools that require specific competences to be correctly interpreted. In this paper we address the issue of analogies' construction between NetLogo simulations and real-world problems by two groups of upper high school students involved in a future-oriented activity. The analysis shows that the students articulate their analogies alternating reasonings that are typical either of the macroscopic or the microscopic level of the simulation. Effective strategies connect these two levels by identifying and discussing the mechanisms of interaction underlying the evolution of the system, leading to more complete and productive analogies.

Keywords: simulations, analogy, models

INTRODUCTION

Computational simulations are a prominent part of an ongoing revolution that, since the 50s, is changing the ways of doing science and conducting research (Hey, Tansley & Tolle, 2009; Vespignani, 2019), especially in those disciplines that deal with complex systems (Bar-Yam, 2016). However, rather than being a prerogative of scientists, professionals, and experts of the respective disciplines, they have reached the non-expert public. Indeed, in the last decade, for the climate change emergency and recently for the COVID-19 pandemic, citizens have been called to enter social debates and decision-making processes also based on these tools (Schultz, 1974; Lyons, Adjali, Collings & Jensen, 2003).

Simulations have been the object of study of many researchers in science education who have investigated their educational potential as well as the challenges they pose to students' learning. Indeed, even simulations commonly used in education (Greca, Seoane & Arriassecq, 2014) are complex tools that embed a variety of knowledge forms, each of them can trigger more or less productive ways of reasoning depending on the context (Barelli, 2022). Moreover, as particular types of models, simulations can challenge novices' understanding: since all simulations represent a "cut" with respect to the simulated phenomena, a mature epistemological posture is required to fully appreciate them as scientific tools (Barelli, Branchetti & Ravaioli, 2019). Because of this gap between "the real" and "the modelled/simulated", understanding and constructing analogies is crucial for students to enter more in depth in the conceptual aspects of the models and simulations, and to become able to apply them in other contexts (Gilbert & Osborne, 1980; Coll, France & Taylor, 2012).

In this paper we present a study conducted with upper high school students during a future-oriented activity in which they had to analyse a real-world problem of their interest and develop future scenarios based on NetLogo agent-based simulations. The goal of this paper is to investigate how students engaged in a process of analogies' development to move from simple "toy" models to complex real-world issues. For the scope of the article, we will not discuss the correctness of students' analogies, because we focus on characterizing their analogical reasoning based on the elements considered.

FRAMEWORK

The educational issue of constructing analogies

An analogy can be defined as "a comparison between two objects, or systems of objects", usually named source and target, "that highlights respects in which they are thought to be similar" (Bartha, 2019). Philosophers of science have conceptualized different forms of analogies, spanning from *material* i.e., the similarity is recognized because of common observations between the source and target domains, to *formal* analogies i.e., source and target are seen as interpretations of the same formal theory (Hesse, 1966). The development of analogies is an authentic scientific practice and many times, in the history of science, analogies have been drivers of scientific discoveries. We can cite for example Maxwell, whose extensive use of analogies with fluid-dynamics was crucial to develop his electromagnetic theory (Nersessian, 1984). In the field of complex systems, the analogical reasoning has allowed to transfer knowledge obtained within a specific domain to different ones, leading to explanations and models in a wide range of disciplinary fields. It is the case of the Ising model, elaborated within physics to describe magnetic properties of materials but that provided the basis for the interpretation of phenomena in social sciences, for example the formation of opinions and voting preferences (Castellano, Fortunato & Loreto, 2009).

In science education, the role and potential of analogies to support conceptual learning has been an issue of discussion for decades (Duit, 1991). Following constructivist views of learning, analogies are retained crucial since they reflect the essential need of understanding the unfamiliar (the target of the analogy) based on what is already familiar (the source). They have a role also in processes of conceptual change as *bridges* that facilitate the "transition of intuitions" from domains known by the learners to other situations that are initially more problematic and not recognized as analogous to the former (Brown, 1994). However, the process of analogy's understanding and construction is not always straightforward for students. They rarely generate their own analogies (Wong, 1993) but, also when they are given a source and a target linked by an analogical relationship, the mapping process often leads the students to alternative conceptions that go beyond the original scope of the proposed analogy (Harrison & Treagust, 2006). Research on cognition at stake in analogical reasonings has pointed out a significant distinction between analogies constructed based on surface elements' likenesses or process similarities (Carey, 1985). The former, that do not involve any causal characterization of the system or object of reference, are easy to map and favour analogy identification, but the latter lead to deeper thinking and conceptual understanding of both the source and target systems or objects (Holoyoak & Koh, 1987). The distinction between surface and process elements, as well as that between material and formal analogies, set the framework for delineating our levels of analogies' construction based on agent-based simulations.

Agent-based approach to the simulation of complex systems

Most simulations of complex systems can be categorized as equation-based or agent-based. In the former case, the system's evolution is described with differential equations; once they are solved, they give the future state of the system starting from the present. On the opposite, in agent-based simulations, the dynamics of the system is generated making the individual agents evolve according to behavioural rules. Since the 80s, researchers in science education have highlighted the potential of agent-based simulations to foster understanding of systems and to enter the mechanistic dimension of local interactions (Wilensky & Reisman, 2006). Indeed, the understanding of the basic mechanisms of natural phenomena is considered a relevant component of students' sensemaking about those phenomena (Kapon, 2016). The same happens with complex systems, where explanations of the emergent properties must lie on the recognition of mechanistic elements of interaction among components (Barth-Cohen, 2018) and on the connection between macroscopic and microscopic levels (Samon & Levy, 2017). For this study, three NetLogo agent-based simulations (Wilensky, 1999) were chosen as the basis for the future-oriented activity.

Wolf-sheep predation implements a predation mechanism. Two kinds of agents (wolves and sheep) move randomly around a grid. When a predator and a prey meet, the wolf eats the sheep. Each movement costs the wolves energy, and they must eat sheep to replenish their energy, otherwise they die. At each time step, each wolf or sheep has a fixed probability of reproducing. For what concerns the behaviour of the sheep, the simulation has two variations. In the case the grass is modelled as infinite, sheep always have enough food and cannot die from starvation. In the second variation, the sheep must eat grass to maintain their energy and when they reach zero-energy die; moreover, once grass is eaten it only regrows after a fixed amount of time. The two variations lead to different evolutions of the system: while with infinite grass unstable dynamics are produced, when a limit is set on sheep's resources, we observe stable dynamics.

Voting implements a model of opinion dynamics. There are two kinds of agents identified with a binary variable - namely the "opinion". At the beginning, the agents are placed randomly on a grid. Each agent, at each time step, counts the number of neighbours of each kind and keeps or changes its own opinion following the majority. Letting the simulation run, the system reaches a configuration with clusters of agents with the same opinion.

Cooperation implements an evolutionary biology model. There are two kinds of agents that differ for their behaviour in consuming food: greedy cows eat the grass regardless of its quantity, while cooperative cows do not eat the grass if it is below a certain height (below a certain height, the grass grows at a slower rate). When the cows eat, their energy increases, and they can eventually reproduce. When the simulation runs, we observe that, if the cows can frequently move around, the greedy behaviour wins, otherwise the cooperative behaviour is evolutionarily successful.

THE FUTURE-ORIENTED ACTIVITY

The future-oriented activity of scenario building through simulations was part of an 18-hours module, designed and implemented online in January-February 2021. The participants were 35 upper high school students enrolled in an optional course on Simulations of Complex Systems, organized within the orientation programs of the National Scientific Degrees Plan in synergy with the IDENTITIES (www.identitiesproject.eu) and FEDORA (www.fedora-project.eu) projects. The module comprised conferences of experts, roundtables with researchers and interactive lectures. A lecture was devoted to the comparison between equation- and agent-based models and the analysis of the three NetLogo simulations presented in the previous paragraph. The module ended with a future-oriented activity (Levrini et al., 2021) in which students were divided in seven groups. The tasks assigned to the students are reported in Table 1. For the purposes of this contribution, we will focus on the first and second task of the activity, where students had to identify a problem of their interest and find a simulation that could help them to model this new problem.

Table 1. Tasks of the future-oriented activity.

Task 1 - Identify the problem
Pick a problem that you feel urgent today and you would like it resolved in 2040. The problem can concern any context: your schools, your city, Italy, Europe, or the whole world. Each member of the group proposes a problem of their interest. Discuss everyone's proposals, then vote for the most convincing one.
Task 2 - Explore different possible futures
Inspiring yourself with the simulation you think is most suitable, explore possible evolutions of the problem from the present to the future and imagine what scenarios you could arrive at in 2040. Describe at least three alternative future situations that the simulation inspired you.
Task 3 - Imagine a desirable scenario for 2040
Now imagine that in 2040 the problem you selected has been solved. Describe in as much detail as possible your desirable scenario for 2040. Include in your description the stakeholders, the interests at stake, how people live in the context in which you are located, the elements of novelty and those of continuity with respect to the past. At this stage... dream! Throw your imagination beyond the obstacles of the present!
Task 4 - Back-casting and action planning
Starting from the desirable scenario, think about what actions, decisions, policies, contingencies made it possible to realize the ideal future in 2040. Were there any bifurcations, moments of uncertainty? What role have the stakeholders played?
Task 5 - Tell the story of success
Prepare a 10-minute presentation to do during the last meeting to tell everyone your success story of which you were the agents, the protagonists. To do this, decide on a name for your group with which to introduce yourself to others, give yourself a role in the story and develop a presentation method (a story, slides, a video ...). In the presentation, highlight the role that simulation has played for you in analysing the problem, imagining the scenarios, and creating your success story.

RESEARCH QUESTIONS AND METHODS

Framed within wider research on the role of agent-based simulations in carrying out future-oriented activities (Barelli, 2022), this study addresses the following research question: *In which ways did 17-18 years-old students constructed their analogies between simulations and real-world problems?* To answer this question, students' discussions in the groups have been video-recorded and analysed. The analytical process used qualitative methods inspired by grounded theory (Glaser & Strauss, 1967) with explicit back and forth dynamics, from bottom-up data exploration to their theory-oriented interpretation (Anfara, Brown & Mangione, 2002).

More specifically, the data analysis process was articulated in three main methodological phases. The first step consisted in performing the transcription and pseudonymisation of the video-recordings. Because we wanted to keep track of how much the single students talked in each line, the transcription also reported the time duration of each line and indicated moments of silence if present. Since the high time cost of the operation (seven groups, 3 hours of videorecording each), we performed the time-marked transcript for one group and compared the time distribution per student with that obtained substituting the time of each intervention with the number of words of the intervention itself, automatically calculated. Given the substantial similarity of the two graphs, we decided to measure the duration of students' interventions in words rather than in seconds. The second step consisted in selecting the parts of transcript in which the students referred to the three simulations to construct their analogies with the problem chosen; these were the parts that we coded with the categories of analogies development that we will present in the next section, obtained through an iterative process of enlargement of the empirical base until saturation. The final step consisted in the analysis of how the collective negotiation of the simulations to use for the future-oriented activity passed through different levels of analogy construction; guided by the obtained picture, we recognized in the succession of codes patterns and recurring elements.

FINDINGS

Microscopic and macroscopic levels of analogy construction

The first result that we want to present is the categorization that we reached about the levels on which the analogies were negotiated and progressively constructed by the students. In particular, they reasoned on macroscopic and microscopic levels. As detailed and exemplified in Table 2, we refer to the *macroscopic level of analogy* when students reason in terms of aggregate, collective features of the system such as: i) its context of application, ii) the scenarios obtained, and iii) the emergent interaction among populations or groups of agents. On the opposite, the *microscopic level of analogy* is related to the elementary "bricks" on which the simulation is built and is detected when students refer to: i) the types of agents of the system, ii) the meaning of parameters and other elements of the simulation, or iii) the models of interaction among individual agents embedded in the simulation. We stress that in both categories related to interaction, there is a reference to the mechanistic dimension and to causal processes. The difference between the two is that in a microscopic perspective the interaction occurs between individual agents (as actually coded in the simulation), while, in a macroscopic perspective, the students reason about an interaction between groups of agents that can only be observed as a result of the simulation's run.

Table 2. Categories of the levels of analogy development and examples of students' sentences.

Macroscopic level of analogy based on the:	
Macro 1 - Similarity between source and target contexts	"We are talking about different ways to see school so we are talking about opinions as in the voting simulation" [F2]
Macro 2 - Similarity between the imagined scenario for the target system and the simulated evolution of the source system	"I was thinking that voting, in the end, remains always constant because it does not describe an evolution… if we want to analyze a teaching method that evolves, voting is not correct because in a while we reach an equilibrium without analyzing how the change occurred… so, with predation is more adequate because we can see how one method disappears and the other grows" [M3]
Macro 3 - Similarity between the interactions among groups of agents	"As in the Lotka-Volterra model there is a fight between groups of people with different opinions" [F2]
Microscopic level of analogy based on the:	
Micro 1- Characterization of the agents	"With the voting simulation we could do that the blue color is the traditional teaching method while the green color is the innovative method that uses new technologies" [M4]
Micro 2 - Meaning of parameters and other elements of the simulation	"We could do that grass in this case is the level of patience of the students" [M4]
Micro 3 - Interaction among agents and other elements of the simulation	"Greedy cows are the old educational traditions and the cooperative cows are the innovative methods. Both are fed by the consensus of students but there are differences. The cooperative tend not to impose themselves to avoid consuming the grass, they spare the food and let it grow, as the students have time to get acquainted with the new methods. The others, the greedy cows, eat and force the students to their will and do not leave them grow" [F2]

Patterns emerging from the distribution of categories

The categories in Table 2 were used to code the parts of groups' transcripts in which the students discussed the choice of a simulation to analyse their problem of interest. To present the results of our analysis we focus on two groups of students that in the future-oriented activity addressed similar problems, both related to school. Group A focused on the predominance of obsolete teaching methods while Group B chose the high level of stress of students in the current organization of the school system. Moreover, the choice of the two groups was motivated by the fact that both analysed their problem of interest in analogy with the three models of reference. The result of the coding procedure is shown in Figure 2. Even if it can be immediately noticed that the discussion in Group A was longer and more articulate than that in Group B, a finer-grained analysis can be conducted looking at how the categories of analogy construction contributed to structure the discussion in the two groups.

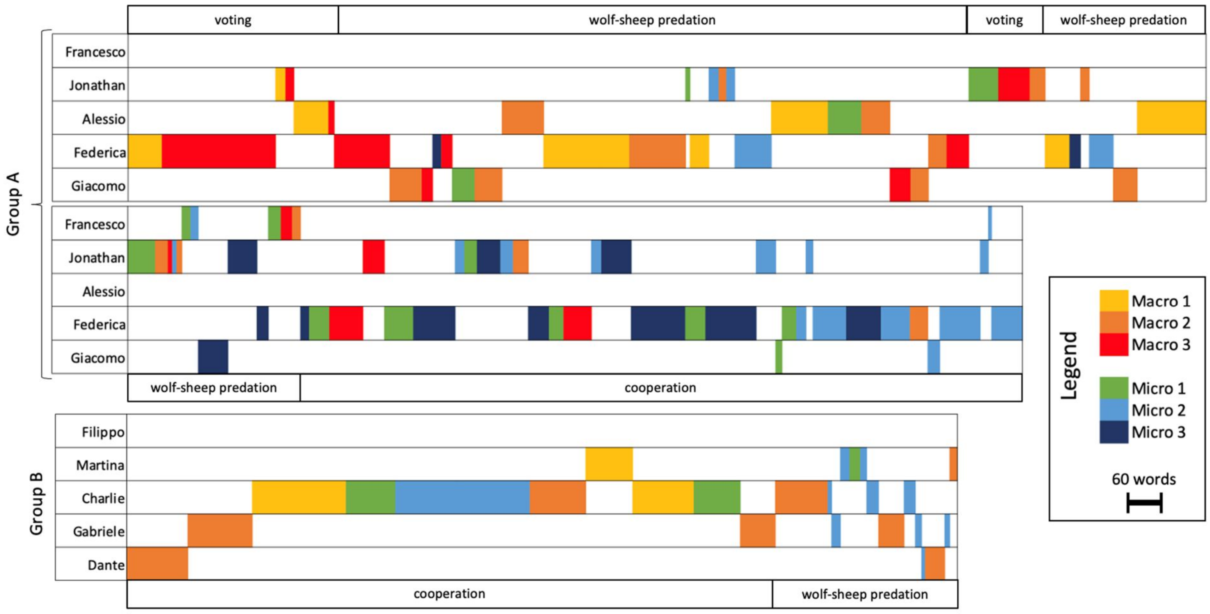

Figure 2. Coding of groups' discussion during the parts of the future-oriented activity in which the students had to choose a simulation to address their problem of interest.

The similarity between source and target contexts (yellow) is a criterion that was considered by both groups in the earliest stages of discussion and was useful to orient the choice of which simulation to take as reference. In Group A, at the beginning of the discussion, observations on the similarity of contexts were followed by reasonings on the nature of interaction between groups of agents displayed by the simulation (yellow-red pairs). This means that, from the beginning, the students not only identified a generic similarity between source and target but were also able to sketch out a possible macroscopic relationship between the groups at stake. This is not the case of Group B, in which the recognition of a similarity of contexts does not reflect an understanding of the underlying or emergent interactions.

As the discussion progresses, the focus on mechanistic dimension progresses from the macroscopic to the microscopic level. Indeed, in both groups we can observe an overall transition from warm to cool colours (even it is more evident with Group A, also due to the longer discussion). In the beginning, the simulations are mainly analysed from a macroscopic perspective; only when these aspects have been discussed, the group can focus on the details of the simulations from a microscopic perspective. It is worth noticing that, in Group A, the transition between macro and micro levels did not occur while reasoning on the same simulation. Indeed, the students were alternating considerations on the wolf-sheep predation and voting simulations until the moment they switched to the cooperation, that was the one they chose in the end. When they moved to cooperation, the students did not need to start from scratch reasoning on the macroscopic levels, such as the likenesses of contexts or the future evolutions of the systems. Indeed, it was the focus on the mechanism of agents' interaction that allowed them to break the previous analogy and move to another one. Then, after negotiating on the new interaction models embedded in the cooperation simulation, Group A was ready to conclude their analysis by mapping the role of parameters and of other elements of the simulation (light blue) in their context of reference. Also, Group B presents a predominance of this level of analogy development in the last part of the discussion, but the lack of a reflection on the mechanistic dimension in the previous part made their analysis rather weak and "blurry". Many interpretations were given to the parameters of the simulation, but none could be argued in the light of an understanding of the underlying mechanism.

A final result that deserves a comment is that in both groups not all the students were equally engaged in the process of constructing analogies. Some of them were completely excluded from the discourse, like Filippo (Group B), and others, like Francesco (Group A), had a marginal role. The case of Alessio (Group A) is even more significant. If we looked at the number and duration of his interventions in the other phases of the whole future-oriented activity, we would see that he was the second most talkative student after Federica for number of words and frequency of speeches. However, when it comes to discuss in depth the three agent-based simulations and develop analogies with the problem of interest, he almost disappears from the discussion and, when he talks, he touches only the macroscopic levels of the analogy, without addressing in any way the issue of interaction.

DISCUSSION AND CONCLUSIONS

In accordance with the cited literature in science education, our findings show that computational simulations are complex objects that are not easy to be correctly interpreted. These difficulties seem, in some cases, to resist instruction, because they have been observed even if the students were guided to analyse these simulations in detail before the task was assigned. In particular, the future-oriented activity made these difficulties emerge because we requested the students not only to analyse a simulation but to move from the level of the model to that of reality, thinking about a real-world issue.

We found that, in constructing their analogies between the source (NetLogo simulations) and their target (a problem of interest), the students put into play reasonings that were typical of the macroscopic or the microscopic level of the simulation. The groups progressively developed analogies alternating, following Carey (1985), observations of the "surface likenesses" of the two systems and a focus on the "similarity of processes" embedded. We stress that, in our categorization, surface-related aspects do not correspond with what we name the macroscopic level. Mapping agents or parameters of the simulations with the analogous elements in the real-life problem refers to a microscopic level of the simulation's analysis but regards issues of surface, since there is not any explicit reference on the processes i.e., the relationships between the agents. On the opposite, the focus on processes and mechanisms can characterize both the microscopic and macroscopic level of the simulation, since in the analogy both interactions between agents and between groups can be mapped.

Effective strategies of analogy's construction connected surface and process, macroscopic and microscopic levels by identifying and discussing the mechanisms of interaction underlying the system's evolution and to which extent these mechanisms were effective in modelling the issue at stake. On the opposite, a lack of focus on the mechanistic dimension resulted in an absence of "discrimination" (from the Latin word dis-cerněre = to separate) criteria: without them, the different interpretations proposed by the students could not be distinguished and the potential of their comparison to construct a more robust analogy remained unexploited.

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