Editors:
Michiel Doorman
Elena Schäfer
Katja Maaß

ICSE International Centre for STEM Education

MOST Meaningful Open Schooling Connects Schools To Communities

STEM & Open Schooling for Sustainability Education

Proceedings of the 4th Educating the Educators Conference

Verlag für wissenschaftliche Texte und Medien
Münster

Naturalis Biodiversity Center

May 11-12, 2023
Leiden, Netherlands

Conference Proceedings in Mathematics Education 11

Conference Proceedings in Mathematics Education

Band 11

STEM & OPEN SCHOOLING FOR SUSTAINABILITY EDUCATION

Proceedings of the 4th Educating the Educators Conference

Michiel Doorman, Elena Schäfer, Katja Maaß (Editors)

Proceedings of the 4th conference Educating the Educators – International Approaches to Scaling-Up Professional Development in Mathematics and Science Education, hosted jointly by the project MOST, ICSE, the ICSE consortium, Utrecht University and Naturalis Biodiversity Museum.
11-12 May 2023 in Leiden, the Netherlands

Layout: Nathalie Kuijpers
Cover: Chrissi Fischer

Published by: WTM – Verlag für wissenschaftliche Texte und Medien, Ferdinand-Freiligrath-Str. 26, 48147 Münster Münster 2024
ISBN 978-3-95987-274-4

The creation of these resources has been co-funded by the Horizon 2020 program of the European Union under grant no. 871155. The European Union/EC is not responsible for the content or liable for any losses or damage resulting of the use of these resources.

Table of Contents

Foreword

Aims and dimensions of ETE IV

Our current society faces enormous environmental challenges. Now is the time to stand up for a sustainable future. This need for action also concerns our STEM education community to make use of the transformational potential of teaching and learning. We need to share good practices, research results and innovative classroom materials that allow for implementing approaches that support the implementation and scaling up of education for sustainability. These actions are broad in scope and attend not only to the practices of teachers, teacher educators and researchers, but also involve other important stakeholders including school principals, policy makers and the students themselves. Moreover, these actions require and appreciate the capillarity of educational institutions and their communities and require collaboration and commitments that ensure educational opportunities and joint responsibilities.

UNESCO initiated a study to explore the expected changes in the role of schools and education in society (UNESCO, 2022). The resulting UNESCO report describes a shift in this role from the 20th to the 21st century. We need to shift from closed school systems to open schooling, from compulsory schooling until the age of 15 to lifelong learning, from school systems separated from communities and discipline-oriented curricula towards learning in multicultural societies, more education-society interaction, open schools and to curricula that fundamentally reorient the place of humans in the world. The UNESCO report creates the need for more holistic approaches to education, such as a Whole School Approach for developing sustainability-oriented teaching that is inclusive and beneficial to all (Mathie & Wals, 2022). We need STEM education addressing environmental issues and promoting active and responsible citizenship (Maass et al., 2022). This shift requires system changes and support for STEM and mathematics and science teachers in implementing new approaches and awareness for intercultural learning (Sorge et al., 2023).

Against this background, the fourth international Educating the Educators (ETE IV) conference was specifically devoted to the topic of STEM & Open Schooling for Sustainability Education. At the conference, we welcomed teachers, teacher educators, policy makers, and various other stakeholders related to STEM education.

ETE IV focussed on implementing and scaling up innovative teaching approaches in STEM education and in particular on open schooling initiatives with respect to environmental issues. Experiences and results gained from the MOST project (2020-2023) and other Open Schooling projects were presented and reflected upon. The aim was to discuss different approaches with a rich variety of participants on three dimensions. The personal dimension referred to the roles and pedagogies involved in teacher education. The materials dimension referred to the resources needed for supporting these pedagogies and specific ways of working. The structural dimension referred to the structures needed for implementing and sustaining innovative approaches to STEM education.

As the Conference Chairs, we would like to thank the countless people, in particular the MOST project partners, the members of the scientific and local organizing committees, and all colleagues who have helped in planning and realizing this conference and who have contributed their wit, energy, commitment and time to make it the successful conference experience.

We would like to thank all attendees for their participation. We hope you gained insights and fruitful exchanges.

The Conference Chairs: Michiel Doorman & Katja Maass

References

Maass, K., Sorge, S., Romero-Ariza, M., Hesse, A., & Straser, O. (2022). Promoting Active Citizenship in Mathematics and Science Teaching. *International Journal of Science and Mathematics Education*, *20*(4), 727–746. https://doi.org/10.1007/s10763-021-10182-1

Mathie, R. G., & Wals, A. E. J. (2022). *Whole school approaches to sustainability: Exemplary practices from around the world*. Wageningen University, Education & Learning Sciences. https://library.wur.nl/WebQuery/wurpubs/fulltext/566782

Sorge, S., Doorman, M., Maass, K., Straser, O., Hesse, A., Jonker, V., & Wijers, M. (2023). Supporting mathematics and science teachers in implementing intercultural learning. *ZDM - Mathematics Education*. https://doi.org/10.1007/s11858-023-01478-3

UNESCO (2022). *Reimagining our futures together: A new social contract for education*. UN. https://unesdoc.unesco.org/ark:/48223/pf0000379707

1. Educating the educators – about the conference series

Elena Schäfer, ICSE

Educating the Educators (ETE) is an international conference series on professional development in STEM (science, technology, engineering and mathematics) education that brings together teacher educators, policy makers, teachers and various other stakeholders related to STEM education.

The ETE conference with the focus on 'STEM & Open Schooling for Sustainability Education' was the fourth conference of the series. The first conference took place in 2014 in Essen, Germany, the second in 2016 and the third in 2019, both in Freiburg, Germany, where ICSE is located.

Background and key topic of the series

Research and experience reveal that innovative teaching approaches promoted by STEM education researchers differ significantly from the day-to-day practices of teachers in many countries. This clearly implies that research on implementing teaching approaches effectively is essential to bridge this gap. These investigations of scaling up should be broad in scope and attend not only to the practices of teachers and researchers, but also to the practices of other important stakeholders including school principals, teacher educators, educational administrators, and policy makers.

Implementing innovations in one classroom can be a challenging endeavour, and it is even more demanding across a whole school. Logically, it becomes exponentially more challenging when the effort of scaling up an innovation aims to reach many schools, a district, or even a state or nation. Therefore, scaling up has become a concern for STEM education research during the last ten years.

In particular, the 'Educating the Educators' conference series serves as a lever and platform for international exchange about concepts and experiences concerning such questions as: What are the features of successful concepts and professional development? What are the needs and experiences of the different target groups? Which pitfalls must be avoided?

The aim is to discuss different approaches, which ensure a high quality of the education of educators:

Personal dimension: Which roles, contents and activities must be considered in the professional development courses for PD course leaders and facilitators in professional learning?

Material dimension: Which role can materials play in professional development for maths and science teachers (classroom materials, face-to-face PD materials and e-learning PD materials)?
Structural dimension: How can projects or initiatives for scaling up professional development look like and how can they be evaluated?

ETE I (2014) was jointly hosted by MaSciL (maths and science for life!, coordinated by ICSE), ICSE (International Centre for STEM Education) and the DZLM (the German Centre for Mathematics Education). This international conference connected researchers and practitioners engaged in the field of maths and science education to discuss concepts of scaling-up teacher professional development. These participant groups are key to the aim of disseminating innovative teaching approaches, such as inquiry-based learning. A special feature of this conference was that it brought together researchers and practitioners (including the target group of teacher educators themselves) and initiated an exchange between teacher education centres in the different countries. Key to scaling-up concepts - and core to the conference - was the education, professional development and support of multipliers. The conference approached the subject from the perspectives of: 1. Individual countries and their particularities; 2. Different target groups and their needs (policy makers, educators of teacher educators) and 3. The end-users (teacher educators, teachers and their everyday classroom practice).

ETE II (2016) took place in the course of the final conference of the project MaSciL ('Maths and science for life!', coordinated by ICSE) and was jointly hosted by MaSciL, ICSE (International Centre for STEM Education) and the DZLM (the German Centre for Mathematics Education). This second conference served as a researcher-practitioner platform for exchange focussing on research, policy and practice relevance and implications. Next to high-level keynote speakers, presentations by researchers and practitioners, a Materials Market, and an Early Career Researcher's Day, the conference also featured a company visit to reflect innovation in STEM education in the industrial context, a Policy Seminar, and hosted a meeting of the Network of European STEM Professional Development Centres.

ETE III (2019) took place in the course of the project MaSDiV ('Supporting Mathematics and Science teachers in addressing Diversity and promoting fundamental Values', coordinated by ICSE), and was hosted by ICSE and the ICSE consortium. In this third conference, the general conference topic was treated in particular in relation to innovative teaching approaches like inquiry-based learning, intercultural learning and connections between STEM learning and fundamental values of our democratic societies. To approach the topic from different angles and to make different stakeholders in STEM education cooperate, we placed particular emphasis on bringing together teacher educators and researchers, course leaders and relevant networks, educators of course leaders and teacher educators as well as policy makers and teacher professional development centres and chose a variety of conference formats to support a vibrant exchange.

ETE IV (2023) was hosted by Utrecht University, ICSE and Naturalis in collaboration with the MOST project, the ICSE consortium and ECENT-ELWIER. ETE IV focused on implementing and scaling up innovative teaching approaches in STEM education, in particular on open schooling initiatives with respect to environmental issues (such as waste reduction, energy reduction/transition, increasing electricity needs for clouds and bitcoins, etc.). The aim was to discuss different approaches with a rich variety of participants on ways of working for teachers and PD course leaders, the roles of teaching materials, and on structures needed for innovations in STEM education. ETE IV featured both traditional and innovative formats to benefit of gathering a circle of participants from research, practice and policy. Vivid exchange and collaborative work were ensured through spaces for co-creation and for sharing ideas and results. Prominent keynote speakers provided rich introductions with two plenary lectures and a panel discussion on the main theme of the conference.

2. Conference hosts ETE IV

MOST (Meaningful Open Schooling Connects Schools To Communities)

The Horizon 2020 project MOST (2020-2023) supports European school students and citizens in developing science knowledge, transversal skills and competences in working scientifically. MOST enables and encourages its target groups to pursue scientific careers and long-term, and will raise the number of scientists in Europe. To achieve this, the Consortium of 23 partners from 10 European countries (higher education institutions, schools, non-formal education providers, ministries, municipalities and enterprises) implemented a powerful Open Schooling idea.

The project opened up formal science education and established new partnerships between schools and their communities (families, science education providers, citizens, businesses, etc.) to work jointly on environmental school-community projects (SCP). These participatory projects directly respond to the needs and values of those involved, benefit the communities as a whole and make schools agents of community well-being. MOST's learning impact was boosted through an educational research-based approach that raises interest in science, scientific literacy and environmental responsibility.

MOST worked on a threefold geographical structure: within communities (schools as hubs) and at a regional level in our 10 partner countries where MOST fairs connected all open schooling communities in a region, strengthening regional effectiveness. At the European level, an Open Schooling Network (EOSnet) was established to sustainably disseminate the results. Finally, the final European MOST conference brought together SCPs from all over Europe and raised awareness among stakeholders about the importance of Open Schooling beyond the MOST partner countries.

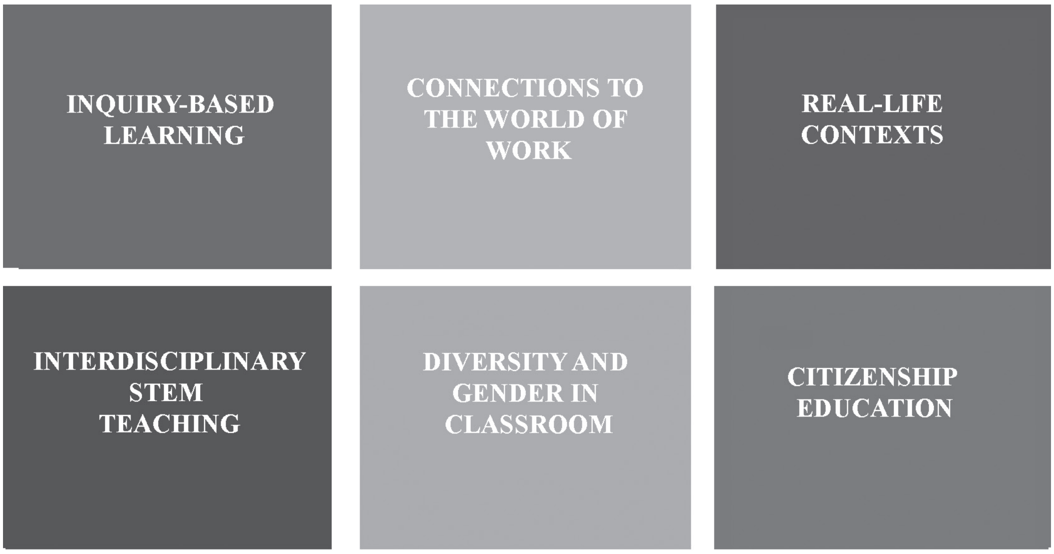
In the course of the MOST project, 672 SCPs were conducted across 10 countries. In total, 78,974 participants were involved, of which 23,113 were students, 2,443 teachers and 53,418 community members (from business/industry, policy, non-formal education providers and wider society). The SCPs represented a large variety of diverse projects tackling challenges which directly affect their (school) community. Best practice examples can be found on the MOST website: https://icse.eu/international-projects/most/

The core of the project was the integration of diverse participants: Science and research, formal and non-formal educational institutions, politics, economy and society – on a local level by cooperating within "Open Schooling" projects, as within the project consortium, which contained all named institutions. The cooperation of diverse participants in co-creation processes was the prerequisite to develop solution approaches, which take the needs of all concerned parties into consideration. At the same time, this is a driver for innovation, which will motivate all participants, to commit in the long term.

The International Centre of STEM Education Freiburg

The International Centre for STEM Education (ICSE) is located at the University of Education in Freiburg, Germany, and focuses on practice-related research and its transfer into practice. The ultimate aim of ICSE is to help to improve STEM (Science, Technology, Engineering and Mathematics) education across Europe. That is, to give students insights into authentic features of STEM subjects and their connection to real-life contexts, to raise achievement levels in STEM subjects and to make science literacy accessible to all students, no matter their gender, their cultural or socioeconomic background. Thereby, ICSE intends to promote the interest of young people in STEM careers.

Our current main foci in our work are on inquiry-based learning, authentic connections to real life and the world of work, interdisciplinary tasks, multicultural aspects and citizenship education in STEM classes.



Foci of ICSE

Our **vision** is that STEM teaching sparks enthusiasm for STEM subjects, supports the development of knowledge of and about STEM, makes learners understand the relevance of STEM for our lives, our world and our future and enables all young people to become responsible citizens.

Our **mission**: We strive to be a central point of contact for all people involved in STEM education: from educational research to non-formal learning providers to policy and the labour market with its innovation-driven businesses.

Our **activities** in these areas include, amongst others, the development, in-situ evaluation and refinement of high-quality classroom materials and professional development materials, conducting professional development courses and student workshops as well as the organization of international conferences and competitions. Furthermore, ICSE develops and executes numerous local and international projects.

To reach these **goals**, three aspects are central to the work of ICSE:

- *Practice-related research*: ICSE focuses on practice-related research. Through the development of teaching materials and professional development courses, we aim to transfer these insights into teaching practice.
- *Working on the international and national level*: We are working, both on the international and national level, to guarantee a prolific exchange between different countries as well as between stakeholders from our local area and within Germany.
- *Cooperation of key actors*: Only through a close cooperation of stakeholders from research, practice, policy and industry, we can successfully develop the future of STEM education.

As we are convinced that sustainable change in STEM education is only possible if all key actors involved in STEM education as listed above, cooperate, we foster this cooperation on regional, national and European level. Therefore, for example, we organize conferences bringing together different stakeholders, such as the conference series “Educating the Educators”, which has been run four times so far (2014, 2016, 2019 and 2023). We also continue to seek cooperation with different stakeholders in various, - mainly European - STEM education projects. In these projects, we design research-based materials for classroom teaching, teacher education and professional development courses and implement related activities, including summer schools or open schooling projects, in partner countries.

For more information on ICSE please visit https://icse.eu/

The Freudenthal Institute at Utrecht University

Utrecht University (UU) is a public institution that was founded in 1636. It is located in the city of Utrecht in the Netherlands. UU is a research university comprised of seven faculties which collectively cover the full spectrum of research and education. Much of the research at Utrecht University is structured around the four strategic themes of dynamics of youth, institutions for open societies, life sciences and sustainability. Some of the university's research institutes are the Copernicus Institute of Sustainable Development and the Institute for Marine and Atmospheric Research. Circa 40,000 students study at Utrecht University.

Part of the university is the Freudenthal Institute for Science and Mathematics Education (FI), situated in the faculty of Science. The FI has master's programmes for history and philosophy of science and for science communication and education (including a track for a teacher degree) with a yearly enrolment of approximately 100 students. The Freudenthal Institute consists of research groups for science education in the subjects of biology, chemistry, physics and mathematics, the History and Philosophy of Science group (HPS) and the U-Talent network in which UU and secondary schools design and improve Science education. The institute aims to contribute to a better understanding of the learning and teaching of science and mathematics. FI research covers a wide range of educational settings, ranging from pre-school education, primary and secondary education to vocational and higher education. Its particular focus is on inquiry-based learning in real-life contexts and in connections between STEM and the world of work. Additionally, research includes the informal learning of students outside school, for example in science museums, and in the workplace. The institute is heavily involved in national descriptions of learning trajectories for science and mathematics in all types of schools. The influence of the work of the institute is reflected in the Dutch curricula, which use contextual situations, support inquiry-based activities and connect students' strategies with carefully chosen didactic models.

The Freudenthal Institute collaborates closely with other science and mathematics education institutes in the Netherlands, for example through national expertise networks, such as Elwier-ECENT in which FI has a leading role (https://elbd.sites.uu.nl/). Schools are an important target group for collaboration. In the U-Talent network, the institute collaborates with more than 45 secondary schools on talent development, teacher training and research (https://u-talent.nl/). These national links are highly important for building open schooling communities and for connecting all those communities within the region of Utrecht in MOST. FI can easily facilitate partnerships between schools and community members.

The Freudenthal Institute offers an international online repository for students, teachers and teacher trainers. In this repository – with more than 250 learning objects in English – you can find research and teaching materials, for primary, secondary and tertiary level (https://www.fi.uu.nl/publicaties/subsets/). The Freudenthal Institute organises annual conferences for teachers in mathematics, chemistry and physics. Its Teaching & Learning Lab is the central location at Utrecht University to experiment with and do research into new educational content and methods. The Lab is literally and figuratively a space for educational innovation (http://teachinglearninglab.nl).

ICSE Consortium

International collaboration is the key to continuous improvements in European STEM education. Together with its longstanding international partners ICSE has therefore initiated the foundation of an International Consortium for STEM Education in 2017.

Representatives of the international consortium at the ICSE inauguration

As an association of 16 higher education institutions and research institutes the consortium unites vast expertise and experience from partners renowned for their research-based work. Our partners all share a unique focus in their research in STEM education: The transfer of research insights into day-to-day teaching. Together, we endeavour to enhance the field of transfer-oriented research and development in relation to STEM education, and to set standards for a high-impact international collaboration of higher education and research institutes.

All consortium partners act in large networks in their respective countries and connect to STEM teaching practice in schools, educational policy, enterprises and industry, non-formal STEM education providers etc. Thus, the consortium operates along the whole science value chain, the jointly developed solutions are transnational and adaptable to each educational setting in each European country.

The consortium was founded to further develop our cooperation and strengthen our network through various measures, such as joint research projects, newsletters, the international exchange of staff and students or summer schools.

The 16 member institutions of the ICSE Consortium:

Austria, University of Innsbruck
Austria, University of Klagenfurt
Bulgaria, Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences
Cyprus, University of Nicosia
Czech Republic, Charles University
Germany, International STEM Centre, University of Education Freiburg
Germany, Leibniz Institute for Science and Mathematics Education Kiel
Greece, National and Kapodistrian University of Athens
Lithuania, Vilnius University
Malta, University of Malta
The Netherlands, Utrecht University
Norway, Norwegian University of Science and Technology
Slovak Republic, Constantine the Philosopher University in Nitra
Spain, University of Jaén
Sweden, Jönköping University
Turkey, Hacettepe University

Naturalis Biodiversity Centre

Naturalis is the national research facility for biodiversity research and the national natural history museum of the Netherlands. The collections consist of over 37 million objects.

Naturalis is a non-profit organisation. Governance is assigned to our managing director, who is accountable to the supervisory board. We also have a scientific advisory board comprised of the most respected scientists in their specialised fields.

With one of the largest natural history collections in the world (one of the top five natural history museums), our labs and our biodiversity data, we offer a unique scientific infrastructure: a veritable time machine that enables scientists to map the biological and geological diversity of the past, present and future. Scientific biodiversity research is fundamental to the protection of the natural riches of our Earth.

Naturalis houses the complete Dutch national collection of 42 million objects and provides state-of-the-art facilities for biodiversity research to the 200+ researchers. Next to that, the institute has also built a brand-new museum. The theme of biodiversity is highly relevant. Naturalis's studies are at the centre of attention, contributing to burning issues such as the global decline of biodiversity on earth, climate change, our living environment, food supply or water quality.

Thus, Naturalis museum was the perfect location to host the conference!

3. STEM and open schooling for sustainability education using the example of the Horizon 2020 project MOST

Sabrina Deck, Sabine Mickler

University of Education Freiburg. International Centre for STEM Education (ICSE), Freiburg, Germany

e-mail: sabrina.deck@ph-freiburg.de, sabine.mickler@ph-freiburg.de

Introduction

Given current global challenges, it is high time to act and learn how we can live together sustainably on our planet. To initiate such a movement, in 2015, the UN General Assembly adopted the 2030 Agenda for Sustainable Development. At the core of it, there are 17 Sustainable Development Goals (SDGs). With these, all 193 member states of the UN have agreed on how to build a sustainable, peaceful, prosperous and equitable world society. However, this requires a profound transformation of the way we think and act. The key to this lies in comprehensive education for all. Therefore, SDG No 4: Quality Education – Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all has a key function in this transformation process: An appropriate education is not only a goal in itself, but also crucial in order to achieve all other goals.

Education for sustainable development

The principles of sustainability are to be anchored in education systems worldwide through Education for Sustainable Development (ESD): "ESD aims at developing competencies that empower individuals to reflect on their own actions, taking into account their current and future social, cultural, economic and environmental impacts, from a local and a global perspective. Individuals should also be empowered to act in complex situations in a sustainable manner, which may require them to strike out in new directions; and to participate in socio-political processes, moving their societies towards sustainable development." (UNESCO, 2017, p. 7) Through ESD, learners can develop cross-cutting competencies such as collaboration competency, critical thinking competency, self-awareness competency and integrated problem-solving competency . These competencies are crucial to understand the increasingly complex and uncertain world in which they live and to deal with the current and future challenges of a rapidly changing environment: "People need to be able to collaborate, speak up and act for positive change." (UNESCO, 2017, p. 10). Together with the key competencies, specific learning objectives of ESD must be pursued: Enabling learners to develop awareness and a critical and contextualised understanding of the 17 SDGs and motivating them to take action for sustainable development. Responsible action is what ultimately matters.

To achieve all this, ESD relies on an action-oriented, innovative pedagogy: All learners should be empowered to take responsibility for present and future generations and actively contribute to societal transformation. Participative teaching and learning methods which empower learners to act should be learner-centred and action-oriented. They should support transformative learning which means to question and change the ways learners see and think about the world to deepen their understanding of it. This also requires a change in the role of the educators to one of being a facilitator of learning processes (Barth, 2015; MOST Pedagogical Guidelines, p. 16ff). It is also recommended that educators and educational institutions should foster partnerships at the local, national and international level to facilitate new ways of learning, integrating different perspectives and experiences: “In a dialogue or a project that includes cooperation with a partner in practice, students can learn about real-world challenges and benefit from the partners` expertise and experiences. At the same time, partners too can be empowered and their capacity as critical agents of change can be increased.” (UNESCO, 2017, p.59).

Open Schooling: An innovative method for STEM teaching and learning

Education for Sustainability Development has become an essential part of international STEM curricula and brought along many transformations of teaching and learning. A participative educational approach which has proved to be successful in providing learners from different backgrounds with the STEM learning experiences mentioned above is Open Schooling: The idea behind Open Schooling is to create new partnerships between schools and their communities. Their purpose is the creation of learning spaces accessible for all citizens to join and let society learn with, about, and from each other: “Open Schooling (is) where schools, in cooperation with other stakeholders, become agents of community well-being: families are encouraged to become real partners in school life and activities; professionals from enterprise, civil and wider society are actively involved in bringing real-life projects into the classroom.” (Science for Responsible Citizenship, European Commission).

Experiences from the Open Schooling project MOST (2020-2023)

The EU-funded project MOST (Meaningful Open Schooling Connects Schools to Communities) intended to support students and citizens in Europe to develop scientific knowledge, transversal skills and competences in working scientifically. The project opens up formal STEM education to citizens and establishes partnerships between schools and their communities to work scientifically together as equal partners on school-community projects (SCP). In an SCP, students work with members of the community (family, academic or non-formal education providers, NGOs, businesses, etc.) on an environmental problem that directly affects their community. Jointly they develop regionally feasible solution approaches. The acquired knowledge will then be delivered to the community. The sharing of results can be accomplished through all sorts of measures, such as short video clips, pictures, posters, flyers, newspaper articles.

Over a two-year period, 672 SCPs were implemented across ten European countries. In total, 78,974 participants were involved, of which 23,113 were students, 2,443 teachers and 53,418 community members. The projects vary in length and group size. But what they all have in common is that they have tried to deal with an environmental issue in real-life contexts by working together with external stakeholders and looking for solutions on how to deal with it.

In all projects, it became obvious from participants' observations and as part of the project evaluation that SCPs build and nurture key competencies.

Working together in their project groups, the participants have developed considerable collaboration competencies. An essential part of the project design was a co-creation process where students and teachers collaborated with experts, scientists, parents and citizens as equal partners and with shared responsibilities on a common challenge. In some cases, these SCPs even inspired further projects at the same or other (school) communities. Thus, the participants were also able to share their experiences in collaborations, becoming mentors or ambassadors for their projects by providing collaborative support.

Moreover, MOST showed that SCPs increase the participants' integrated problem-solving competency. All projects focused on real-life contexts and dealt with questions relevant to them as a group or to the whole (school) community. Dealing with those authentic questions in an inquiry-based learning setting automatically meant that results were open and unpredictable or unexpected challenges had to be overcome as part of the scientific process, individually or as a group. Due to the meaningfulness and relevance of the chosen topics and tasks, a high level of motivation could be perceived, which positively influenced integrated problem-solving competencies. Moreover, the participants' different backgrounds led to multi-perspectivity and interdisciplinarity, which also enriched the problem-solving process.

Another essential competency nurtured through MOST was critical thinking. In their projects, all participants actively discussed current issues in the field of sustainability and acquired new STEM and general knowledge. Jointly, they debated various perspectives the different partners could provide, covering scientific, socio-political, economic, environmental or psychological impacts of their project topics. Ultimately this type of project design does not only raise people's awareness for sustainability, but also develops their communication, decision-making and negotiating skills. It may even sharpen their values and lead them to questioning traditional ways and perspectives. Therefore, encouraging critical thinking also becomes a vital component in the promotion of democracy.

Another interesting observation is that the MOST projects also supported self-awareness competencies. In the course of the SCPs, participants have become aware of their own skills, values and desires and they could discover their own talents and passions. There was also space for the participants to try out new roles - for example, adults learning from students; or for adults to take students' ideas and thoughts seriously. Moreover, SCPs were safe spaces where mistakes became learning opportunities instead of flaws and where non-stereotypical gender representations were offered. In general, participants had time to reflect on their own actions and learned for example how good it feels to make a difference together, even if it is only on a smaller scale at first.

Overall, the development of these four competencies within the MOST project clearly led to the achievement of the specific ESD learning objectives mentioned at the beginning:

Participants gained an overall awareness for Sustainable Development through their new (STEM) knowledge and increasingly understood environmental processes. They have learned that there are no easy solutions, but that many factors, perspectives and influences have to be taken into account to move forward. This also includes making mistakes, going in the wrong direction, and then coming back and starting over again. However, it also became clear to many participants that this new awareness comes along with a new responsibility to take action as well. This last step has proven to be significant in order to counteract students' frustration and hopelessness, e.g., about the current state of the environment or the way politics is dealing with it. Participants can experience themselves as a community that finds solutions to a difficult situation together. Therefore, the main goal of Open Schooling often comes as a relief and also as a guide for action: To look for real-life problems and find practical solutions allows for a positive take-away for the project participants. They can really achieve something for the whole (school) community, they have changed something for the better or at least they have tried to do something instead of waiting around. In this way, the participants directly experience that their actions have an effect. Because in the end, it is all about making a difference, even if it is only on a small scale. But also about the knowledge that we can make great changes if many people in many places take small steps.

And this exact feeling of empowerment can manifest itself in several ways. The participants felt empowered to:

– act and respond to complex situations and challenges
– to overcome their own shortcomings, fears, insecurities, worries (sometimes as part of a shared group experience)
– to shape their own future

Eventually, this specific type of open schooling experience can affect whole communities on various levels and can empower all participants from students to teachers or citizens to transform existing structures, thus making them significant agents of change in terms of educational transformation, responsible (environmental) citizenship and community-wellbeing.

Summary

Education for Sustainable Development “asks for an action-oriented, transformative pedagogy, which supports self-directed learning, participation and collaboration, problem-orientation, inter- and transdisciplinarity and the linking of formal and informal learning.” (UNESCO, 2017, p. 11). The MOST project has taught us that this is exactly what Open Schooling can offer. Therefore, it represents a great illustration of modern quality education in the way it is proposed by the SDGs and also a concept that is worth spreading amongst educators across Europe.

Inspiring best practice examples of MOST School-Community projects can be found here:

References

Barth, M., (2015). *Implementing sustainability in higher education: Learning in an age of transformation*. Routledge.

European Commission, Science for Responsible Citizenship. *Open Schooling and collaboration in science education*. last update: 13 April 2022, Accessed: 29 June,2023 https://cordis.europa.eu/programme/id/H2020_SwafS-01-2018-2019-2020

MOST project, lead contributions by Norwegian University of Science and Technology (NTNU), Dept. Teacher Education (2023). *Pedagogical Guidelines and Exemplary Science Materials*. Accessed: 29 June, 2023, https://icse.eu/wp-content/uploads/2023/07/MOST-D4.2-Pedagogical-guidelines-and-exemplary-science-materials.pdf

UNESCO (2017). *Education for Sustainable Development Goals, Learning objectives*. Unesco.

UNESCO (2021). *Reimagining our futures together – A new social contract for education*. Unesco.

UNESCO & Deutsche UNESCO-Kommission e.V. (20121). *Bildung für nachhaltige Entwicklung. Eine Roadmap*. Unesco

4. Keynotes

Learning our way out of systemic global dysfunction: Rethinking STEM education in the Capitalocene

Arjen Wals

Wageningen University, the Netherlands / UNESCO Chair

Abstract

Our planet is in crisis. Interrelated global challenges like runaway climate change, mass extinction, extreme wealth inequality and global pandemics, are affecting billions of people across the globe as well as other species. Many people, especially young people, worry about the future that lies ahead. This existential threat poses questions about the role of education. Can we learn our way out of this crisis? What is the role for STEM? In my keynote I tried to provide some answers using the perspective of a Whole School Approach to realizing quality education that is relevant, responsible, re-imaginative and hopeful in light of urgent global challenges.

Introduction

Planet Earth is in trouble, not by its own doing, but the activities of one single species: homo sapiens. In the last 100 years or so, humankind has not been so kind to the planetary boundaries that support life on this unique planet (see, for instance, Rockström, 2009). Major earth systems, like the climate, the web of life, ocean currents, etc., that have been formed over more than 4 billion years are changing in a very short period of time. Granted, not all humans are responsible for this, but especially those who have come to cherish, expand and export, a way of thinking that is based on management and control thinking, expansion and growth, linearity and extraction, and the idea that there is only one exceptional species that is entitled to what the Earth has to offer. The evidence is overwhelming that we are on a collision course that is already leading to the 6th period of mass extinction, but this time not caused by natural phenomena. In the meantime, many children today fear a future plagued by environmental catastrophes such as mass extinctions, runaway climate change and social ills such as rising inequality. Climate anxiety is a new term that has been recognized by the American Psychological Society. Many young people suffer from such anxiety and risk lapsing into depressing and apathy (Taylor, 2020). It is no surprise that there are climate strikes and other forms of resistance and that schools are looking for ways to deal with such anxiety in a systemic way (Kvamme et al., 2022).

A new role for education

Welcome to the Anthropocene or, perhaps more accurate, to the Capitalocene (Pedersen et al., 2024). What is the role of education in today's world? How can our schools develop the qualities and competencies humanity needs to be able to live more lightly, equitably and healthily on the planet? If we fail to address these questions, schools risk becoming an extension of the globalizing economy that seems to favor a world of unbridled consumerism. Just as business-as-usual is no longer an option, neither is education-as-usual. Three innovative education reforms are being tried to prepare students for a sustainable future. The first approach ('add on') is well-intentioned but problematic. A second approach ('build-in') is more promising, while a newer third approach ('systemic re-design') appears to have the most potential and is gaining traction.

Approach No. 1: Add to Existing Curricula

Educators and school districts around the world are considering ways to incorporate the 17 sustainable development goals (SDGs) proposed by the United Nations in its 2030 Agenda for Sustainable Development. The UN Agenda includes social goals (no poverty; gender equality; zero hunger; peace, good health and well-being; reduced inequality; and peace, justice and strong institutions); ecological goals (clean water and sanitation; climate action; life below water; and life on land); economic goals (decent work and economic growth; industry, innovation and infrastructure; and responsible consumption and production); goals requiring social, ecological and economic reforms (affordable and clean energy; and sustainable cities and communities); and mechanisms to achieve all these goals (quality education and partnerships for the goals). Teaching students about the UN goals spans multiple disciplines and requires social and emotional learning and reflection on ethics and values. But previous studies on education innovations have demonstrated we cannot keep adding to existing curricula (e.g., OECD, 2020). Schools cannot become the dumping grounds for solving all societal ills. Should we add every topic covered by UN goal -- all equally important -- the curriculum would overload teachers who are challenged enough already covering basic subjects. The add-on approach can do more harm than good as interest groups compete for their pieces of the curriculum pie. Topics may not be addressed in sufficient depth and teaching materials developed by interest groups may lack educational quality. Nevertheless, this approach can be useful if policy and governance goals are built in to curricula more organically.

Approach No. 2: Build-in

In this more promising approach, educators, curriculum developers and textbook publishers are exploring ways to incorporate sustainability concepts into existing topics.

For example, chemistry students can learn the composition and toxicity of plastics and how they react with salt water when they become part of the oceans' "plastic soup". Biology courses can teach how aquatic life and food chains are affected by toxic pollutants. And math courses can help students understand climate change statistics, for instance as used in the latest IPCC-report, or the exponential growth of plastic pollution in the oceans. Mathematics can be used to explore social justice issues, such as the distribution of wealth in the world, also looking at race, gender and social class. Another example from geography class might be linking sustainability and social justice issues involving smartphones (Maxwell and Miller, 2020): Where do rare earth metals used in making smartphones come from? Or from biology class: How does rare earth mining affect local biodiversity? Or from social studies and economics: What are the working conditions in the mines? How is the wealth distributed in the chain? Or from health sciences: How does smartphone use affect concentration, social relationships, and our connection to the physical environment in which we live? Ideally, there would be some synergy between these subject areas which brings us to the third approach. STEM education seems to connect best with this approach, provided it does not by itself gets coopted by neo-liberal tendencies that seek to preserve the status quo (Smith & Watson, 2019).

Approach No. 3: Whole School Approach to Sustainability

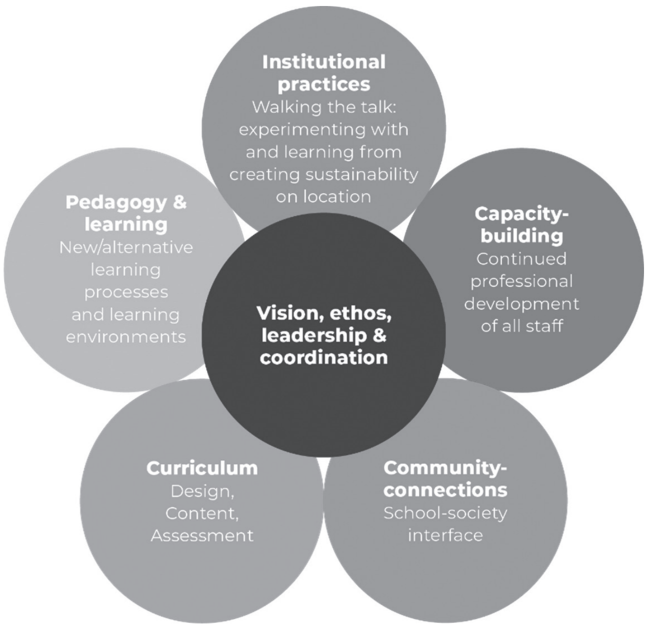


Figure 1. A Whole School Approach to Sustainability (Wals & Mathie, 2022)

This third way is catching on in schools, with support from UNESCO (UNESCO, 2021), the European Union and the United Nations Economic Commission for Europe, along with NGOs such as the Foundation for Environmental Education's EcoSchools' program, which includes 59,000 schools worldwide. Under the whole school approach, sustainability, good health, well-being and democratic citizenship are woven into the school's DNA. It involves every part of the school – the janitor as well as the principal and the school building and school grounds as well as the classroom. Figure 1 shows the components of such a Whole School Approach (WSA) to sustainability.

Researchers at Wageningen University & Research in the Netherlands and at the Norwegian Life Science University have been researching the whole school approach to sustainability for a number of years now and a number of key features have emerged over the years (Wals & Mathie; Mathie & Wals):

- Students are given a voice and encouraged to participate in school leadership and governance.
- Curriculum is more localized, interdisciplinary and rooted in existential questions.
- New forms of learning are used, such as place-based learning (which connects students to their communities) and challenged-based learning (which challenges students to develop solutions to complex, real-world problems).
- The school becomes a living sustainability lab, including sustainable forms of energy use, responsible and healthy cafeteria food and green playgrounds. The school might even offer a "repair cafe" – a place equipped with tools and materials for community members to repair their clothes, furniture, bicycles, etc. Or have a closer look at the food that is consumed by students and staff (see; rethinking school lunch – Center for Ecoliteracy, 2010)
- Professional development classes and workshops are offered to janitors, secretaries and other support staff, as well as of course to teachers and principals.
- The entire community becomes a living laboratory for meaningful learning which implies good relations with local NGO's, CSO's, local government, local businesses, local farmers, and, people living in the neighborhoods of the school.
- The school organization, leadership and ethos are all well-aligned in supporting a whole school approach.

Together with Norwegian PhD candidate, Rosalie Mathie, and with the help of many teachers and school leaders from around the world, we recently identified critical best practices of enacting such a whole school approach. We called them critical best practices as we were not just looking for celebratory 'feel-good' case studies that only tend to share successes but for practices that also share the struggles and challenges they encounter. The investigation yielded 19 case studies that include schools in the United States, Canada, South Africa, India, Mongolia, Norway, the Netherlands, Turkey, Finland and Uruguay. Based on our findings, and previous research, we have drawn the following lessons (https://www.wur.nl/en/education-programmes/wageningen-pre-university/whole-school-approach.htm):

First, we need to have more confidence in the abilities of teachers and students and give them the freedom to learn and experiment without being held in a straitjacket of prescribed curricula and a culture of accountability. Let them develop a curriculum rooted in their community. It is not easy, and it requires working with the community. But when students are empowered to act upon what they learn, it will make education more responsible, relevant and responsible.

Second, do not try to oversimply the complex issues of health, sustainability and good citizenship. For example, making the school cafeteria more sustainable involves much more than eliminating bottled water. It will take a deep dive into the effects the cafeteria has on water and energy use, fairness, affordability, gender issues, animal well-being and carbon footprint along the entire food chain, from soil to plate. This can raise difficult, even discomforting questions – such as the morality of eating meat – that will not have definitive answers. It also will require a sound understanding of science, the ability to distinguish facts from myths and a critical reading of media sources.

Third, many young people are worried about their future. Some are protesting or demanding education reforms. Others succumb to psychic numbing and apathy. The challenge is to replace fear with hope. Educators need to show students how to make changes, however small, in themselves and others. This requires learning environments that invite students to articulate their own change challenges, (co) design action plans, evaluate their impact, learn from the attempts and to try again or to move on to the next challenges.

Fourth, it's possible to become competent, innovative and creative but still end up accelerating unsustainability if we lack the underlying ethic of care and compassion for other people, other species and the entire earth. Teachers and schools in general tend to shy away from contemplating moral stances. But if we are to take sustainability seriously, we must face the tough moral choices.

Finally, achieving a whole school approach to sustainability will require big changes in the education and professional development of teachers. Teachers need to learn how to: negotiate values, ethics and social emotional learning in the classroom; connect different disciplines to emerging topics; find teachable moments; connect classroom learning with community-based learning; use the school and school grounds as a living laboratory; and use alternative forms of assessment that go beyond testing and measuring. Up to now, such skills have received little attention in education schools and in-service training.

Conclusion

Educational priorities must change. If we are to move towards a more sustainable world, education must serve the wellbeing of the people and the planet, not just the economy. This requires moving away from a culture of testing, measurement and accountability to create spaces where learners can experientially investigate existential issues rooted in their life-world and local environment while being mindful of the bigger picture. In addition, it is critical that educators look for ways to replace a culture of fear and powerlessness with a pedagogy of hope, space for action and an ethic of care. Doing so also implies the acknowledgement of the importance of socio-emotional and embodied forms of learning. Lastly, in seeking to engage in sustainability in meaningful ways, schools might, at least in some parts of the world, be able to take advantage of emerging tensions and dynamics in policybvframeworks in connection to education and climate. For STEM education and openvbschooling this is an invitation to realign and redesign education, learning and schooling from a systemic, critical and socio-ecological perspective that allows for boundary-crossing and engagement in the key questions of our time in a hopeful way.

References

Center for Ecoliteracy (2010). Rethinking school lunch: A planning framework from the Center for Ecoliteracy. Accessed June 1, 2022. https://www.ecoliteracy.org/sites/default /files/rethinking_school_lunch_guide.pdf

Kvamme, O.A., Sinnes, A., & Wals, A.E.J. (2022). School Strikes as Catalysts for Rethinking Educational Institutions, Purposes and Practices, *NORRAG* Special Issue on Education in Times of Climate Change, 7, 85-90.

Mathie, R. G., & Wals, A.E.J. (2022). *Whole School Approaches to Sustainability: Exemplary Practices from around the world*. Wageningen: Education & Learning Sciences/Wageningen University. 62 pages. https://doi.org/10.18174/566782 Available online via: www.wur.nl/wholeschoolapproach

Maxwell, R., & Miller, T. (2020). *How green is your smartphone*? Polity Press.

OECD (2020). *Curriculum Overload – a way forward*. OECD. https://doi.org/10.1787/3081ceca-en

Pedersen, H. Windsor, S. Knutsson,B., Sanders, D., Wals, A., & O. Franck (Eds.) (2024). *Education for sustainable development in the 'Capitalocene*', Educational Philosophy and Theory Series. London: Routledge.

Rockström, J., et al. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, *14*(2), 32.

Smith, C., & Watson, J. (2019). Does the rise of STEM education mean the demise of sustainability education? *Australian Journal of Environmental Education*, *35*(1), 1 – 11. https://doi.org/10.1017/aee.2018.51

Taylor, S. 2020. Anxiety disorders, climate change, and the challenges ahead: introduction to the special issue. *J. Anxiety Disord.*, 76, 102313. https://doi.org/10.1016/j.janxdis.2020.102313

UNESCO. 2021. *Reimagining Our Futures Together – A New Social Contract for Education*. UNESCO. Accessible via: https://unesdoc.unesco.org/ark:/48223/pf0000379707.locale=en

Wals, A. E. J., & R. G. Mathie (2022). Whole school responses to climate urgency and related sustainability challenges. In M. A. Peters & R. Heraud (Eds.), *Encyclopedia of Educational Innovation*. Springer.

School-community projects as keys to sustainability education in the STEM domains

Marta Romero-Ariza

University of Jaén (Spain)

e-mail: mromero@ujaen.es

Abstract

School Community Projects (SCP) arise from students' concerns and communities' needs and actively engage different stakeholders in the solution of local sustainability problems with global implications. During the process, students have the opportunity to meaningful apply science and mathematics to co-create sustainable solutions, improving life in their schools, families and communities. Building on inspiring examples and research evidence from regional case studies, this contribution identifies the key features of good SCP and the main barriers for a successful implementation. Quotations from different stakeholders provide low-inference statements illustrating the wealth of learning outcomes arising from those initiatives.

Introduction

What if STEM and sustainability education are far away from seeding the sense of ownership and empowerment people need to fully engage in the creation of a better world? What if we are not hearing important voices? What if we are not giving room for shared inspiration and creativity? What if we are failing in really engaging people (from the youngest to the oldest) and losing capacity and talent in our societies? Are our schools actually triggering scientific literacy, fundamental values, knowledge, capacities and commitment to face current environmental and societal issues?

Open Schooling (OS) has been proposed as a powerful way to address these concerns and to respond to contemporary educational needs. OS involves learners in meaningful real-life problem-solving situations in collaboration with various stakeholders, to ensure that young people and adult learners alike are motivated to learn and to be fully equipped to engage in scientific discourse in society (European Commission, 2022), achieving and exhibiting scientific literacy (OECD, 2016; Romero-Ariza, 2027).

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

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

This work was conducted within a European project to improve STEM and sustainability education through School Community Projects (SCP), as a way of OS. Within the project, students actively engaged in the investigation of local problems related to waste and energy in order to co-design with experts and other members of the community, sustainable solutions, while meaningfully applying STEM knowledge and skills.

A multiple case-study approach (Yin, 2017) was applied to better understand what were the key characteristics of successful SCP and the main supporting and hindering factors. In the content analysis of individual and group interviews special attention was paid to capture how participants experienced SCP and which evidence was available about students' learning outcomes.

Key features and outcomes of school communities projects

Regarding the key features of good SCP, the content analysis of qualitative data shows the importance of focussing on real-life problems felt as relevant by participants, planning in advance and getting school and community support, as well as linking the project to the school curriculum. Participants also expressed positive feelings related to satisfaction, pride and enjoyment. Regarding the main barriers for a successful implementation, teachers usually refer to lack of time or experience, a rigid school curriculum and organisation and sometimes, difficulties to collaborate with other colleagues and engage external agents. They require recognition of their efforts and bigger support and flexibility to run such projects.

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

Acknowledgement

Research funded by the European Union under grant agreement № 871155.

References

Ariza, M. R., Boeve-de Pauw, J., Olsson, D., Van Petegem, P., Parra, G., & Gericke, N. (2021a). Promoting Environmental Citizenship in Education: The Potential of the Sustainability Consciousness Questionnaire to Measure Impact of Interventions. *Sustainability*, *13*(20), 11420.

Ariza, M. R., Christodoulou, A., van Harskamp, M., Knippels, M. C. P., Kyza, E. A., Levinson, R., & Agesilaou, A. (2021b). Socio-scientific inquiry-based learning as a means toward environmental citizenship. *Sustainability*, *13*(20), 11509.

Broman, K., Bernholt, S., & Christensson, C. (2022). Relevant or interesting according to upper secondary students? Affective aspects of context-based chemistry problems. *Research in Science & Technological Education*, *40*(4), 478–498.

European Commission (2022) https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-widera-2022-era-01-70

King, D., & Ritchie, S. M. (2012). Learning Science Through Real-World Contexts. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education*, (pp. 69–79). Springer.

Maass, K., Sorge, S., Romero-Ariza, M., Hesse, A., & Straser, O. (2022). Promoting Active Citizenship in Mathematics and Science Teaching. *International Journal of Science and Mathematics Education*, *20*(4), 727–746.

OCDE (2016). PISA 2015 *Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy*. OECD Publishing. doi: 10.1787/9789264255425-en

Romero-Ariza, M. (2017). Inquiry-Based Learning: is there enough evidence of its benefits in science education? *Revista Eureka sobre enseñanza y divulgación de las ciencias*, *14*(2), 286–299.

Sisnetwork (2016). *Science education policies in the European Commission: towards responsible citizenship*. Retrieved from http://www.sisnetwork.eu/media/sisnet/Policy_Brief_Science_Education.pdf

Yin, R. K. (2017). *Case study research and applications*: *Design and methods*. Sage.

5. Conference outcomes and conclusions

Discussion on 'How do we envision education-oriented communities to stand-up for sustainability?'

Jesper Boesen, Elena Schäfer

"STEM & Open Schooling for Sustainability Education" – as the theme points out, the conference provided a platform for insightful discussions and engaging dialogues on the role of education-oriented communities in promoting sustainability education. One of the highlights of the conference was a thought-provoking panel discussion that captivated the audience's attention and inspired them to envision a future where education and sustainability intertwine harmoniously.

Under the theme of "How do we envision education-oriented communities to stand up for sustainability?", the panel discussion sought to explore the obstacles and opportunities faced in this pursuit. The session aimed to foster a co-creation mindset and shed light on the importance of open schooling and sustainability education. By bridging the gap between policy and practice initiatives, the discussion aimed to create an inspiring atmosphere around co-creation experiences.

The plenary panel discussion revolved around the complex and interdisciplinary aspects of socio-scientific issues such as climate change, energy transition, and waste reduction. The speakers, representing various perspectives, reflected on these critical issues and emphasized the role of education in preparing students to become active agents for sustainability within their communities.

Include open schooling and sustainability education topics in initial teacher education – promote that the job of a teacher is a job that can do something – can support and empower and really make a change.
- Jesper Boesen

One of the notable participants in the panel was Rivka Meelis, a passionate student from FridaysForFuture in the Netherlands. The panel also included Natalia Serrano Chumilla, a dedicated teacher from the Centro de Profesorado de Jaén in Spain, Caroline Lewis-Jones, a dynamic school leader from Birralee International School in Norway, José María Sanchís, an experienced policy maker from the Conselleria d'Educacio de Valencia in Spain, and Jiří Kulich, an engaged NGO representative from The Rýchory Centre of Environmental Education and Ethics in the Czech Republic. Harold Brockbernd enriched the discussion by adding an additional dimension to the discussion by being a teacher and a climate activist of Extinction Rebellion.

The panel discussion was moderated by Jesper Boesen, a researcher from Jönköping University, Sweden, who also was a partner in the MOST project. Throughout the 60-minute session, the audience was actively engaged with the help of interactive elements such as an interactive live feed of questions, resulting in a lively discussion with the auditorium. Jesper provided a brief introduction, emphasizing the environmental challenges we face and highlighting the significance of education-oriented communities in addressing these issues. The introduction incorporated insights from the UNESCO report titled "Reimagining our futures together: A new social contract for education," which stressed the importance of diverse and open schools that fundamentally reshape the role of humans in the world.

Enable young people to experience that they can change something, that they can contribute – that is the best action.
- Jiří Kulich

Environmental topics in the perspective of youth

As a first key interest, Rivka was asked what youth does see for challenges regarding environmental topics and what do they learn about them in school? Rivka summarized that in many cases, the education system does cover the topic of climate change, usually in science classes. Students learn about the causes and effects of climate change, including concepts like greenhouse gases, the carbon cycle, and the role of human activities. However, as Rivka mentioned, the broader social and environmental implications, as well as the actionable steps individuals can take, may not receive sufficient attention.

In school, there is the topic 'Climate change,' but that's only it – nothing about social impact, responsibilities, the urgency to act now.
- Rivka Meelis

Rivka's example of showering for two minutes gave a valid point. While it is common knowledge that conserving water is important, many young people may not fully grasp the significance of their individual actions, such as reducing shower time. Understanding the environmental impact of such actions can help youth make more informed choices and contribute to sustainability efforts. Thus, in Rivka's opinion, educators can help youth better understand their role in addressing climate change by integrating real-life examples, practical guidance, and highlighting the interconnection between personal choices and climate outcomes.

As an experienced school leader, Caroline stressed that when teaching environmental topics to students, it is important to strike a balance between raising awareness and empowering them without overwhelming them with stress or anxiety. Ways to tackle this challenge, according to Caroline, can be found in providing age-appropriate information, in focusing on solutions and in promoting action-oriented learning (providing opportunities to take action and make a positive impact). This way, educators can teach environmental topics in a way that empowers students, cultivates their sense of responsibility, and encourages them to take positive action, all while avoiding overwhelming stress or a sense of helplessness.

Bridging the gap: Addressing sustainability education in school

The discussion amongst the panelists emphasized that balancing the requirements of the curriculum with addressing environmental topics and challenges of sustainability education is indeed important for fostering sustainable development and empowering young people. Besides incorporating environmental content into existing subjects, Jiri also suggested to empower young people by providing them with opportunities to experience like implementing student-led interdisciplinary projects, so that they realise they can make a difference and contribute to change.

Schools have to pay attention to sustainable education to reconnect with nature. - Natalia Serrano Chumilla

Jose emphasized the need for action, as doing nothing is never a good solution. Collaboration with local environmental organizations like non-profit organisations or government agencies can, according to Jose, be one first step. They can provide students with firsthand experiences and insights into environmental issues and inspire them to take action. The key is to find ways to integrate environmental topics into the existing curriculum, rather than treating them as separate entities. By doing so, you can fulfill the curriculum requirements while instilling a sense of environmental responsibility and empowering young people to take action.

There is no hope without action.
– José María Sanchís

Being a teacher, Natalia knows that it is not always easy to fulfil the curriculum and still get to topics of sustainability education or to carry out open schooling projects. For Natalia, a high engagement of the teachers themselves is needed, and, in addition, the support of the school leader is essential. She experienced that there is a certain degree of power and support if students themselves actively express their wishes and needs on such topics to also motivate teachers to have an open-minded look on the integration in the curriculum. This is an essential part of student leadership: Encourage and empower students to take leadership roles in promoting sustainability within their school and local communities. Natalia stresses that it is the task of school and society in general to plant seeds in our students to be messengers to their surroundings and to further give it to the new generation.

We give trust to our teachers. Our teachers are very creative, and they have to be, otherwise space and place for open-schooling does not help at all. - Caroline Lewis-Jones

Open schooling: individuals and segments of society that have not been effectively engaged or should be included

Jesper noted that in the realm of open schooling, it is crucial to consider individuals or sections of society that have not been adequately engaged and should be included. Thus Jesper asked the panelists about their assesment of these excluded groups. Caroline highlighted the actors of industry, such as professionals and practitioners from various fields, as they could contribute valuable knowledge and expertise to open schooling initiatives. However, according to Caroline, it is also important to address the needs of marginalized groups like refugees and individuals who do not speak the languages commonly used in open schooling platforms. Efforts should be made to ensure their inclusion and overcome language barriers to enable them to benefit from open schooling opportunities.

Is there a political dimension in teaching education for sustainable development topics in school?

The audience raised a question on how to handle a situation where a teacher believes that an environmental topic has political dimensions but wants to remain neutral in their teaching? In dealing with teachers who believe an environmental topic has political dimensions but wish to remain neutral, Harold suggests that

Transparency is better than neutrality – in societies we just have different opinions. The students could also look critically at their teachers.
- Harold Brockbernd

transparency is preferable to neutrality. He emphasizes that societies naturally have diverse opinions, and students should have the opportunity to critically analyze their teachers' perspectives. Harold acknowledges that climate change inherently carries political implications. As a geography teacher, he aims to serve as a connection point between geography and society, enabling students to form their own judgments and facilitating open debates in the classroom. According to Harold, steps can be to clarify the concept of neutrality, to directly encourage critical thinking (foster an environment where students are encouraged to think critically and form their own opinions - teachers can facilitate classroom discussions that explore different viewpoints, allowing students to analyze and evaluate the political dimensions of the topic) and to promote transparency (in the sense of encourage teachers to be transparent about their own biases and political beliefs while maintaining professionalism). The latter also means that teachers can openly acknowledge that political dimensions exist but make it clear that their role is to present information and foster critical thinking rather than advocate for a specific viewpoint. This way, balancing neutrality with transparency and critical thinking can help create an engaging and informative learning environment, according to Harold.

Final question: "What is a utopian view formulated today on: How do we envision the future and how would a school collaboration perspective ideally look like?"

In summary, the perspectives shared regarding an ideal school collaboration scenario are as follows:

- Rivka suggests that every teacher should incorporate the climate crisis into their subject and advocates for a designated space in schools where students can learn about societal issues like climate change.
- Jose highlights the relevance of EU policy documents, which outline sustainability competencies and emphasize the need for countries to honour the agreed deals.
- Natalia expresses her dream of reopening a school with increased student engagement in green activities.
- Juri believes that schools should serve as examples of sustainability, involving both the institution and students in decision-making processes, fostering interdisciplinary connections, engaging with external actors, and promoting social and environmental responsibility.
- Caroline acknowledges the school's desire to be involved but suggests allocating a dedicated hour each week to address sustainability, considering it as an essential aspect similar to the allocation of time for other topics.
- Harold emphasizes the importance of taking the first step and encourages individuals to be heroes.

These perspectives highlight the desire for schools to actively engage in addressing issues such as the climate crisis, integrating sustainability into the curriculum, involving students in decision-making, and serving as role models for responsible and environmentally conscious behaviour. Ultimately – and that is what the discussion showed – the goal is to equip young people with the knowledge, skills, and motivation to become active participants in addressing climate change and creating a more sustainable future.

6. MOST policy seminar

Opening up school education: Ways to support schools on their path to institutional change

Sabine Mickler[1], Gultekin Cakmakci[2]

[1]University of Education Freiburg, [2]Hacettepe University

To meet the global challenges of our time, we need citizens who are used to thinking in an interdisciplinary and solution-oriented way, who have the courage to act and take responsibility. To this end, we need concepts and educators in STEM subjects that more closely align research, innovation, and practices in science education with the needs and ambitions of society and reflect its values. Education is the key to societal change. A promising approach for a high-performing school of the future is to open up school education and let society learn with, about and from each other: In the European MOST project, schools were supported to open the doors of their classrooms to work on projects in real-life contexts in collaboration with community members. In these participatory projects, participants tackled an environmental challenge relevant to their community and brought their respective expertise to the problem-solving process. Here, the schools get involved in the community, the participants experience themselves as self-effective and learn with, about and from each other.

Although educational systems must constantly face societal changes, they often seem to be less flexible when it comes to spontaneously adapting to these changes. Therefore, it is desirable to establish a particular space within the curriculum or timetable to provide opportunities to open up schools not only in terms of content but also structure. In doing so, open schooling can become a driving force of institutional change.

The need for Open Schooling

The MOST policy seminar was a part of the European MOST conference at ETE IV in Leiden, the Netherlands. Together with different stakeholders from research, policy and practice, it discussed the importance of integrating Open Schooling activities into the curriculum and how to institutionalise this promising teaching and learning method in the longer term.

Giuseppe Mossuti, European Schoolnet, opened the seminar by introducing current challenges in STEM education. He highlighted that Open Schooling offers solutions to these challenges as it allows communities to invest in the next generation, it helps teachers to shift from content-based teaching towards process-based learning, it fosters collaboration between schools and local communities and gives students a sense of agency.

Subsequently, Antonio Quesada, University of Jaén, reported empirical evidence on benefits of MOST Open Schooling projects to justify why it is so important and useful to integrate Open Schooling approaches into the curriculum. The preliminary results are promising and these evidence-based findings and suggestions are important in making education policy stakeholders aware of the impact and importance of Open Schooling.

Tobias Feitkenhauer, Initiative "Schule im Aufbruch" (schools on the move), stresses that there is an urgent need to introduce new learning formats that provide students with the necessary skills to take responsibility in a rapidly changing world. He reports on the learning format "FREI DAY" as an inspiring example of how participatory projects can be institutionalised in schools. FREI DAY reserves a free space in the school week in which students work independently on topics of their own choice. The focus is on future issues, with the 17 Sustainable Development Goals providing the framework. The students acquire knowledge about the topic they have chosen themselves and act together: They develop projects at school, in the community or in the city, which they implement themselves. This learning format creates a space for participation and self-efficacy experience through action – it opens up schools and also opens up mindsets.

Ways forward to open up schools

After the informative part of the seminar, the following questions were discussed in various small groups within the framework of a world café: What do teachers need to integrate Open Schooling activities into their lessons? What are the challenges and how to overcome them? And how can actors in the education sector contribute to pave the way for Open Schooling activities in the curriculum?

In the discussions, all participants stressed the importance to connect the learning in school within real-life contexts by collaborating with externals in participatory projects. Above all, teachers need to have space to implement these kind of learning formats during day-to-day teaching as well as more freedom to work on curriculum topics in an interdisciplinary and participatory way. Breaking new ground often also means that teachers have to commit themselves beyond their regular working hours, therefore there are organizational and financial aspects to be considered as well. This is where teachers need the support of their school leadership. In addition, the teachers would like to have adequate teacher training that gives them an understanding of new learning and teaching methods and closely accompanies their implementation, also in exchange with other colleagues as a Community of Practice. Support is also needed from the political arena in order to make the aforementioned freedom and resources to implement new learning formats and to enable the accompanying transformation of school education on exactly the ground that UNESCO and the global community are striving for.

Summing up, Gultekin Cakmakci, Hacettepe University, concluded by emphasizing the importance of opening up schools, universities, industry and society for sustainable open school education and subsequentinstitutional change. He pointed out that the mission of universities, in particular, should also go beyond an education and research-based orientation and allow for closer collaboration between academia, industry and society, as well as a stronger focus on global challenges with interdisciplinary co-creation research.

7. MOST Fair

Ragnhild Staberg[1], Monica Wijers[2], Sanne Korte[2], Lucas Weinberg[3]

[1]Norwegian University of Science and Technology, [2]Utrecht University, [3]University of Innsbruck

e-mail: ragnhild.l.staberg@ntnu.no

At the MOST fair students and their teachers presented 18 school community projects from 9 countries. In the MOST project, students and their teachers collaborated with their communities (families, science education providers, citizens, businesses etc.). Together they worked on environmental issues with a thematic focus on waste management and energy saving. These participatory projects directly responded to the needs and values of those involved, benefitting the community as a whole and making schools agents of community well-being. Teachers, students and SCP-leaders presented posters, gave pitches, showed materials and video's or carried out an experiment for an audience of conference visitors in a lively atmosphere. Especially the exchange between students from different countries was great to see.

Recommendations from participants included suggestions like:

"Maybe invite people that can actually make all the plans and ideas happen in more places or cities or even countries."

"I have no improving for the Most Fair.
It was just great, specifical the moderation and how they taught us to share our projects/ connect with each other etc. Please keep that!"

The evaluation showed that visitors very much valued the presentations and also the conversations with students, teachers and other people involved in the SCPs. They were also happy with the way it was structured to encourage interactions and fruitful exchange of experiences to move beyond only walking around and passively looking at the various posters.

When asked what aspect of the fair they liked best, many visitors appreciated the participation of the students. Teachers rated the international MOST Fair as a very good opportunity to disseminate their SCPs. Meeting others who have done similar projects and sharing good practices and stories were highly appreciated. The students also appreciated meeting students and teachers from other countries, exchanging ideas and discovering commonalities.

“They were also students like me that wanted to help their school. And they were very dedicated too”, one student recalled.

Figure1. participants at the MOST fair

8. Papers

A key-competence approach to teaching standard topics in STEM

Michiel Doorman[1], Željka Milin Šipuš[2], Andrej Šorgo[3], Annette Lykknes[4], Lucas Weinberg[5], Martin Bilek[6], Katja Maass[7]

[1]Utrecht University, Utrecht, Netherlands

[2]University of Zagreb, Zagreb, Croatia

[3]University of Maribor, Maribor, Slovenia

[4]NTNU, Norwegian University for Science and Technology, Trondheim, Norway

[5]University of Innsbruck, Innsbruck, Austria

[6]Charles University, Prague, Czech Republic

[7]University of Education, Freiburg, Germany

e-mail: m.doorman@uu.nl

1. Introduction

The European Commission has identified the urgent need to support the development of citizens' key competences (European Commission, 2019). Higher education institutions (HEIs) play a major role for this support, as they are the ones to educate future teachers. Core of STEM education at school is the transfer of fundamental subject knowledge like functions, measurement and chemical reactions. However, in traditional teaching, learners' skills and attitudes in these standard topics have not been sufficiently. Therefore in the key competence approach (COM 2019) key competences play a major role. They consist of knowledge, skills and attitudes and mathematical competence, competences in science, technology and attitudes and digital competences belong to eight key competences as highlighted by the EU. addressed in a key-competence STEM teaching approach (Maass et al., 2019). The challenge for HEIs is to learn teachers to teach key competences without neglecting subject structures needed for further study (e.g. Ploj Virtič & Šorgo, 2016).

Topics bearing controversial aspects or obvious societal relevance – such as environmental degradation or cybersecurity – require innovative educational approaches, which enable teachers to not only deliver knowledge but also foster learners' skills and attitudes. New approaches are needed to connect traditional topics to these transversal competences. This creates the need to figure out ways to allow learners to develop key competences in the scope of these traditional topics. Unfortunately, only a few materials are available on teaching STEM content with the potential to foster the development of key competences, because these materials are often not explicitly connected with traditional curricula (Šorgo et al., 2022).

In the European STEMkey (2020–2023, Erasmus+ KA2) project, several countries collaborated to develop modules for teacher education with the aim to learn future teachers to teach standard STEM topics with a key competence approach in order to reshape the delivery of standard STEM topics with their interdisciplinary connections. STEMkey is a project implemented by the International Centre of STEM Education at the University of Education in Freiburg in cooperation with 10 partners out of 10 European countries. In the following we will outline some of the modules in order to give insight into the key competence approach.

2. Exemplary insight into the teaching modules based on the key competence approach

2.1 Teaching functions

As for many approaches to STEM education, it is essential to gain the students' interest and to show them the relevance of functions. Even though most people do not realize it, but they use functions in many all-daily situations, be it to calculate a taxi fare with fixed start price and per kilometre travelled (linear function), the trajectory of a ball (quadratic function) or the spread of a virus (exponential function). The current situation in relation to the corona virus and societal measures shows how important it is to fundamentally understand the concept of exponential growth to act responsibly. This module starts off from open realistic situations and students are asked to mathematically model them. Mathematical modelling can simply be understood as applied mathematical problem solving, and thus involves connecting mathematics and the world around us, applying mathematics and inventing mathematics to solving problems, and therefore serves sense making in mathematics education (Drijvers et al., 2019). The module discusses how to work with open and interdisciplinary tasks, and how to orchestrate the classroom activities that support students' autonomous construction of knowledge, investigation of strategies and presentation skills. Additionally, we know that different function aspects can be better understood by using different function representations, graphs, tables, rules or verbal descriptions (Bloch, 2003) and therefore students work with these various representations. This also offers obvious use of digital tools for the purpose of analysing functions and their representations.

2.2 Teaching measurement

Measurement provides answers about sizes of objects or phenomena and applies to basic physical quantities like length, area, volume, weight, time, speed, force and energy. These quantities can be primary (e.g., length and time) or compound quantities (e.g., speed). Measurement competences have become increasingly important in our current digital society and are needed in daily life and in the workplace. However, in day-to-day teaching, measurement is treated in an abstract way with a focus on conversions of measures and practicing the staircase model. The aim of this module is to provide a rich learning experience for future teachers and demonstrate the relevance of being able to apply measurement concepts and use them to solve situations in their personal and professional lives. The module also addresses a variety of qualitative and quantitative dimensions (e.g. for acid or wind) and includes attention for everyday language like micro, kilo and tetra. Measurement is addressed with modern (mobile) tools that are needed for meaningful and critical use of technology (Gravemeijer et al., 2017). Future teachers need to understand the potential of using modern technology in their classroom, and they need to learn how they can instruct their students how to use them in today's society

2.3 Human anatomy and physiology with smartphones

Human anatomy and physiology is part of almost all primary and secondary school curricula in the world. Most of the time it is taught as a part of life science subjects, but basically every teacher, regardless of the subject, sooner or later comes across questions that connect traditional topics from his/her subject with human beings. To illustrate, we can look at the flow of energy that connects physics and chemistry to metabolism, all in social, societal, technological, and environmental contexts. Thus, teaching and learning on these topics can be seen as challenging. The search overarching principles and transversal key competences is expected to be a preferred avenue for finding connections. This module provides activities that can be used in the classroom or outside the classroom based on observation, counting, and measurement using tablets or smartphones. The hands-on activities have been tested with students - prospective biology teachers - as part of the regular curriculum in biology didactics and will be transferred to a course. So far, in addition to the introduction (know your smartphone), three activities based on observation (smartscope), counting (smart heart), and measurement (coagulation of proteins) have been tested and protocols have been established. It was shown that the introduction of such activities in the courses for prospective teachers has the potential not only to improve knowledge, experimental and practical skills, but also to enhance competences like creativity, critical thinking, problem-solving strategies and to support positive attitudes.

2.4 Teaching the periodic system

To science educators the periodic system is an invaluable tool that facilitates a succinct organization and understanding of building blocks of chemistry. Indeed, the compressing of chemical knowledge that the system offers, once initiated a transformation in teaching, from forcing students to cram brute facts – as was the fashion in the 19th and early 20th centuries (Kaji et al., 2015) – to learn by studying relationships between elements and trends in chemical properties across the table. In this module, we offer a context-based approach to introducing the periodic system to teacher students which at the same time might inspire their own future teaching about the subject in lower secondary school. A context-based chemistry teaching requires that students connect canonical science concepts with a real-world context, a connection that makes chemistry meaningful to students (King, 2012). The module includes sorting activities using Lego bricks, an introduction to the historical development of the periodic system, hands-on interaction with samples of elements, as well as socio-scientific issues related to the extraction and use of chemical elements in technological devices. By selecting elements that the students might know from their everyday lives and disseminate about their applications in society— including ethical issues– we connect the "inhabitants" of the periodic system, and thereby the system itself to real-life contexts.

2.5 Moving from theory to experience - Teaching material cycles

Learning about material cycles – and the carbon cycle in particular – bears the potential to unite different STEM subjects across the curriculum and to provide interdisciplinary learning opportunities. Curricula of various subjects highlight the importance of material cycles. In physics classes students shall learn about the water cycle and in geography and economy classes students shall encounter different cycles that are relevant to our geo-ecosystem, including the water and carbon cycle. It is crucial that (future) STEM teacher are capable to teach the ubiquity by (a) creating learning environments that allow for interdisciplinary learning instead of multidisciplinary learning of isolated pieces of knowledge, and (b) helping learners to integrate single pieces of knowledge to gain a systemic understanding of the carbon cycle. This module shows future STEM teachers how to teach material cycles in a real-world context using practical activities, which increase learners' perceived relevance of the topic (Zeyer & Dillon, 2019). This is important, because teachers typically ask learners to reproduce knowledge on the different systems, chemical compounds, and chemical reactions of material cycles and explain graphics given in textbooks. Future STEM teachers need to experience how they can support learners to apply knowledge on material cycles in real-world contexts and develop critical thinking, which is one "of the requirements to navigate our increasingly complex world" (European Commission, 2019, p. 3).

Critical thinking results when knowledge, skills, dispositions (or attitudes) and norms, values and emotions interplay when dealing with a subject or an object to take a position, make a decision and/or act and this process is controlled by intellectual standards as well as self-regulation (Rafolt et al., 2019).

2.6 Teaching chemical reactions

Chemical reactions are a standard topic in chemistry education and therefore initial teachers need to be prepared for it. However, in traditional science classrooms this topic is often treated by showing one example and then by treating chemical equations without direct connections with experimental activities. The aim of this module was to develop an innovative teaching material on the topic Chemical reactions with rich learning experiences for school students which also nurture the development of key competences. Chemical reactions are introduced in concrete examples from everyday life and in supporting of sustainable development (industry, agriculture, transport etc.). Our focus is to introduce future teachers into ways of transforming standard "content" into tasks which give student an active role, which use real-life contexts, connect different disciplines and take into account students' diversity. Experiments support the understanding of mutual transformations of chemicals where material cycles are associated with significant colour changes in substances, changes in the reactant state and variety of reaction types (Kolář et al., 2018). These experimental activities require creative and critical thinking, and aim at enabling future teachers to teach the basics of chemical reactions in an innovative way.

3. Summary

This paper gives exemplary insight into modules for future STEM teacher education with a focus on supporting not only the the acquisition of facts but on the key competence approach. The materials are available online under https://icse.eu/international-projects/stemkey/.

Acknowledgements

STEMkey is funded by the ERASMUS+ grant program of the European Union under grant no. 2O2O-I-DEO1.KA2O3.OO5671. Neither the European Commission nor the project's national funding agency DAAD are responsible for the content or liable for any losses or damage resulting of the use of the project's resources.

References

Bloch, I. (2003). Teaching functions in a graphic milieu: What forms of knowledge enable students to conjecture and prove? *Educational Studies in Mathematics*, *52*, 3–28.

European Commission (2019). *Key competences for lifelong learning*. https://data.europa.eu/doi/10.2766/569540

Drijvers, P., Kodde-Buitenhuis H., & Doorman, M. (2019). Assessing mathematical thinking as part of curriculum reform in the Netherlands. *Educational Studies in Mathematics*, *102*, 435–456.

Gravemeijer, K., Stephan, M., Julie, C., Fou-Lai Lin & Ohtani, M. (2017). What Mathematics Education May Prepare Students for the Society of the Future? *International Journal of Science and Mathematics Education*, *15*, 105–123.

King, D. (2012). New perspectives on context-based chemistry education: using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education*, *48*, 51–87.

Kaji, M., Kragh, H., & Pallo, G., Eds. (2015). *Early Responses to the Periodic System*. Oxford University Press.

Kolář, K., Bílek, M., Machková, V., Rychtera, J., & Chroustová, K. (2018). Experimental Cycles as Alternative Approach to Teaching the Topic Chemical Reactions. In K. Miecznikowski (Ed.), *14th European Conference on Research in Chemical Education „Educational innovations and teacher needs" - Book of Abstracts* (pp. 7–8). Warszaw University.

Maass, K., Geiger, V., Romero Ariza, M., & Goos, M. (2019). The Role of Mathematics in interdisciplinary STEM education. *ZDM Mathematics Education*, *51*(6), 869–884.

Ploj Virtič, M. & Šorgo, A. (2016). Can we expect to recruit future engineers among students who have never repaired a toy? *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(2), 249–266.

Rafolt, S., Kapelari, S., & Kremer, K. (2019). Kritisches Denken im naturwissenschaftlichen Unterricht – Synergiemodell, Problemlage und Desiderata. *Zeitschrift für Didaktik der Naturwissenschaften*, *25*(1), 63–75.

Šorgo, A., Dolenc, K., & Virtič, M. P. (2022). Challenges and opportunities in incorporating entrepreneurial competences into pre-university schools for all. *International Journal of Management in Education*, *16*(1), 1–19.

Zeyer, A. & Dillon, J. (2019). Science | Environment | Health – the emergence of a new pedagogy of complex living systems. *Disciplinary and Interdisciplinary Science Education Research*, *1*(9), 1–10.

A professional development session on environmental socio-scientific issues and its impact on prospective mathematics teachers' task designs

Katerina Bogiatzi[1], Chrissavgi Triantafillou[1], Maha Farah[1], Vasiliki Spiliotopoulou[2], Despina Potari[1], Giorgos Psycharis[1]

[1]NKUA Mathematics Department, Athens, Greece

[2]School of Pedagogical and Technological Education (ASPETE), Department of Education, Greece

e-mail: kbogiatz@math.uoa.gr

Abstract

This study explores one teacher educator's actions while enacting a professional development session on environmental socio-scientific issues for prospective mathematics teachers in the context of a European project. The focus is also on the extent that this session could support the participating prospective mathematics teachers' exploitation of these issues. We analysed the teacher educator's actions and resources as well as the prospective teachers' task designs with respect to their authentic, social and controversial characteristics, and the modelling steps required to be carried out for their enactment. The results indicate that supporting sustainable education for prospective mathematics teachers is feasible.

Keywords

environmental socio-scientific issues, prospective mathematics teachers' task designs, teacher educator's actions

1. Introduction

The literature suggests that there is a need for developing a Professional Development (PD) model to prepare European prospective mathematics and science teachers to integrate Environmental socio-scientific issues (EnvSSIs) in science and mathematics classrooms (Maass et al., 2019). It seems that this integration is challenging for mathematics teachers, primarily due to their ill-preparedness in leading debates on such topics and the perception that mathematics is a politically-neutral and context-free domain of knowledge (Barwell et al., 2022; Evagorou, 2011; Owens et al., 2019). Thus, exploring ways of enacting a PD session addressed to prospective mathematics teachers (PMTs), in order to support them in designing tasks relevant to EnvSSIs; and the impact of this session on PMTs' designs could be of interest in the field.

The present study took place in the context of a European Project (ENSITE, https://ensite-project.eu/) aiming to enrich prospective teachers' competences for designing and implementing EnvSSIs in mathematics and science classrooms. In the context of this project, several modules were designed and piloted in many

European Universities. Particularly, four Greek teacher educators (TEs) designed and enacted short Professional Development (PD) sessions to support prospective mathematics and science teachers to include in their teaching practices tasks on EnvSSIs. This paper reports on one of these cases.

This study explores a TE's actions while enacting a teaching session on EnvSSIs for Postgraduate Mathematics Teachers (PMTs) and the extent that this session could support PMTs' exploitation of these issues. The research questions are:

RQ1: What are the TE's actions aiming to support PMTs to teach EnvSSIs in mathematics classrooms?

RQ2: What is the impact of the TE's actions on PMTs' exploitation of EnvSSIs in their task designs?

2. Literature review

Hauge and Barwell (2022) propose the following two principles for designing PD courses to support mathematics teachers to teach EnvSSIs: a) exploring meaningful situations of risk and uncertainty and b) incorporating both scientific/mathematical concepts and societal perspectives. Furthermore, linking environmental issues with task authenticity is evident in many studies. Specifically, the environmental issues seem to possess the following essential authentic task characteristics: a) the out-of-school origin and b) the certification of originality, so that to engage students in authentic, meaningful, and context-driven mathematical modelling processes addressing societal concerns (Yaro et al., 2020). Thus, the modelling cycle has been recently extended to include modelling steps relevant to citizenship education (Maass et al., 2023).

3. Context and Methodology

The PD session we study here was part of the undergraduate course entitled 'Teaching through Problem solving-Mathematization' based mostly on parts of the modules developed in the ENSITE project and lasted for 7 teaching hours. In the course's final assignment, 47 PMTs (working in groups of 2-3) were asked to design a mathematical problem that concerns an environmental issue of their choice; present the relevant socio-scientific issue; and provide the sources used in their design. PMTs designed 22 tasks.

The data for this study are a) the TE's lectures and teaching material and b) PMT's task designs. The TE's lectures were analysed in terms of her teaching actions and goals. The analysis of PMTs' task designs and the resources the TE used in the PD session was carried out in two phases. In the first phase, all materials were analyzed by focusing on four dimensions: a) their authenticity; b) the emphasis given on the societal aspects and the c) controversial aspects of the problem; and d) the identification and further use of mathematical modelling steps needed for enacting the specific tasks as described by Maass et al. (2023, p. 138). These steps include: understanding the task (step 1); collecting information, analyzing sources (step 2); mathematizing (step 3); using mathematics (step 4); interpreting the mathematical solution (step 5); validating the mathematical solution (step 6); discussing contradicting results (step 7); and decision making by considering ethical, social, cultural and economic aspects (step 8). In the second phase, we selected three exemplary TEs' resources and five PMTs' task designs to illustrate the existence or non-existence of the above dimensions.

4. Results

4.1 TE's actions enacting the PD session.

a) Inviting four PMTs who participated in an online ENSITE Multiplier event to introduce EnvSSIs to their classmates. The goal of this action was to familiarize PMTs with EnvSSIs and their controversial side.

b) Suggesting and discussing specific Environmental tasks that could be used in mathematical classrooms. These tasks were developed in the ENSITE project. Some of these tasks were the *Climate change*, the *Ecological footprint*, and the *Lake drainage* tasks. The goal of this action was to specify the mathematical modelling processes involved in these tasks. The presentation of the tasks was mostly based on steps 1 (introducing PMTs to the specific environmental issue), then by providing pre-defined mathematical models and mathematical solutions, the PMTs had to move to steps 5 (interpreting the mathematical models), step 7 (discussing possible contradicting results) and step 8 (decision making based on ethical/social/cultural aspects). For example, in the *Ecological footprint*, graphs based on authentic resources from three different countries were given. These graphs show the bio-capacity evolution from 1961 to 2016 in the specific country. PMTs first had to understand the meaning and importance of the ecological sustainability of a specific area as well as the relation between the area's bio-capacity and the ecological footprint of humans living in this area (step 1). Then, PMTs were requested to study, interpret and compare the data on the graphs (step 5) and suggest ways to decrease the ecological footprint of a country and to deal with the problem of ecological deficit and physical unsustainability that this country may face (Step 8).

c) Implementing an online survey quiz with the question: "Paper or plastic bags, which is better for the environment?". In this activity, PMTs had to read several resources and provide an argument for the one or the other choice. Subsequently, PMTs were asked to analyze their classmates' arguments by using the Toulmin's framework. The goal of this action was to support PMTs' evaluation of arguments.

d) Using a digital calculation tool to engage PMTs in counting their ecological footprint with the goal to sensitize them on relative issues.

Thus, the TE emphasised the controversial characteristics of EnvSSIs (Actions a, c); raised PMTs' sensitivity to such issues (Actions a, d); and supported students to acknowledge the mathematical aspect of these issues (Action b). On the other side, the TE provided examples based on pre-defined mathematical models while no validation was needed for these models.

4.2 PMTs' exploitation of EnvSSIs in their task designs.

Among a number of PMTs' interesting answers, five proposed assignments indicate PMTs' exploitation of EnvSSIs.

(a) The *Fire fighting* task: the students had to develop ways to prevent forest fires, explore the main causes and make the better choice of trees for reforestation.

(b) The *Railway* task: the students had to decide on the expropriation of a piece of land to benefit from a new railway track.

(c) The *Fashion Ecological Footprint* task: the students had to explore ways to lower the ecological footprint from clothing production.

(d) The *Sinking Village* task: develop ways to rescue a sinking village in Indonesia.

(e) The *Donation* task: choose the best way to recycle plastic for making a donation to a disabled person.

Some extracts from PMTs' tasks are: 'Study the energy consumption of trains versus cars and state the benefits from each choice' (*Railway*); 'where would you put the factory, if you wanted the least CO_2 emission and the lowest production cost?' (*Fashion Ecological Footprint*); 'Argue on the following question: Pine tree: just a beautiful tree or real bomb?'(*Fire fighting*); 'Save the village of Timbulsloko by creating a protection zone planting bamboo or mangroves trees. Which is the best choice?' (*Sinking Vvillage*).

As regards the modelling steps for solving the corresponding problems, all tasks aimed to introduce students to the environmental problem (step 1) and take into account their controversial aspects (step 7). For example, the negotiation in terms of profit and cost was present in *Sinking village*, *Railway* and *Fashion ecological footprint*. In two tasks, students had to interpret pre-defined mathematical models (step 5). For example, in *Firefighting* students had to use statistical measures to interpret the models given and discuss the best ways of reforestation and firefighting means. In three tasks, students had to construct mathematical models (step 3) and the mathematical solutions (step 4) based on the given information. For example, in the *Railway* students had to develop the arithmetical progression of the CO_2 emissions amount per year. Only the *Sinking village* can be considered as a 'holistic modelling task' (Maass et al., 2023, p. 141) as it required students to carry out almost all modelling steps. Specifically, students were asked to collect information from given resources (step 2), develop specific mathematical models (step 3), calculate the area and the cost of planting the trees (step 4), interpret the results and argue on different type of trees to be used (steps 5, 7) and make choices taking into consideration specific social and cultural aspects such as the urgency to save the cemetery. In none of the PMTs' task designs were students asked to validate their mathematical results (step 6).

The societal aspect was also ascertained in all the above tasks. We can list for example, the reference to a recent and catastrophic Greek fire that caused the deaths of many people (*Firefighting*); the priority of rescuing a cemetery (*Sinking Village*); the promotion of the value of volunteering (*Donation*); and the sensitivity to global self-awareness about the planet's climate change (*Fashion Ecological Footprint*).

Finally, all of the above tasks maintained original and authentic characteristics since they were different from those that the TE presented in her lectures and they were based on authentic resources such as: national data (*Firefighting*, *Fashion ecological footprint*, *Sinking village*); online articles, newspapers and magazines (*Firefighting*, *Donation*, *Sinking village*);sites about environmental issues https://adoptabeach.wwf.gr/schools (*Donation*), https://climate.nasa.gov/vital-signs/sea-level/ (*Sinking village*); world Resources Institute: https://www.wri.org (*Fashion ecological footprint*); and research papers (*Firefighting*, *Sinking village*, *Fashion ecological footprint*).

5. Conclusion

This study provides an example of introducing global realities to PMTs through the design of a short PD session based mostly on high quality and ready-to-use materials that were developed in the context of the European Project ENSITE.

The TE emphasized the controversial and the societal characteristics of EnvSSIs and she tried to raise PMTs' sensitivity to such issues. The above characteristics were also identified in the five illustrative examples of PMTs' task designs. Even though the TE used examples with pre-defined mathematical models, the PMTs attempted to design tasks that could include the development of mathematical models. Validation of the mathematical models and solutions was absent in the TEs' teaching materials as well as in PMTs' task designs.

Thus, the TE needs to develop more or different actions to stand up for her students to learn how to integrate all the modelling steps of the extended modelling cycle into their designs. The inclusion of holistic modelling tasks in mathematics teaching could support students to relate mathematics with issues relevant for society (Maass et al., 2023). The originality and the authenticity of PMTs' task designs show the potentiality of related mathematics teaching with EnvSSIs. The supporting elements in this direction are the careful design of PD sessions and the high-quality and ready-to-use materials developed in the ENSITE project.

This study suggests that if these short PD sessions become functional parts of specific undergraduate courses in the upcoming years, it could be the start of supporting sustainable education in respect to EnvSSIs for prospective mathematics teachers (Maass et al., 2019).

Acknowledgments

The project ENSITE received funding from the European Union Erasmus+ Programme under grant agreement no. 2019-1-DE01-KA203-005046. This paper reflects only the authors' views, and the European Union is not liable for any use that may be made of the information contained herein.

References

Barwell, R., Boylan, M., & Coles, A. (2022). Mathematics education and the living world: A dialogic response to a global crisis. *The Journal of Mathematical Behavior*, *68*, 101013. https://doi.org/10.1016/j.jmathb.2022.101013

Evagorou, M. (2011). Discussing a socio scientific issue in a primary school classroom: The case of using a technology-supported environment in formal and non-formal settings. In T. Sadler (Ed.), *Socio-scientific issues in the classroom*, (pp. 133–160).

Hauge, K. H., & Barwell, R. (2022). Education for post-normal times. In R. Herheim, T. Werler, & K. H. Hauge (Eds.), *Lived democracy in education: Young citizens' democratic lives in kindergarten, school and higher education* (pp. 65–76). Routledge.

Maass, K., Doorman, M., Jonker, V., & Wijers, M. (2019). Promoting active citizenship in mathematics teaching. *ZDM*, *51*(6), 991–1003. https://doi.org/10.1007/s11858-019-01048-6

Maass, K., Zehetmeier, S., Weihberger, A., & Flößer, K. (2023). Analysing mathematical modelling tasks in light of citizenship education using the COVID-19 pandemic as a case study. *ZDM*, *55*(1), 133–145. https://doi.org/10.1007/s11858-022-01440-9

Owens, D. C., Herman, B. C., Oertli, R. T., Lannin, A. A., & Sadler, T. D. (2019). Secondary science and mathematics teachers' environmental issues engagement through socio-scientific reasoning. *Eurasia Journal of Mathematics, Science and Technology Education: Special Issue on Enhancing Environmental Literacy in K-12 Science Classrooms*, *15*(6). https://doi.org/10.29333/ejmste/103561

Vos, P. (2018). How real people really need mathematics in the real world—Authenticity in mathematics education. *Education Sciences*, *8*(4), 195. https://doi.org/10.3390/educsci8040195

Yaro, K., Amoah, E., &Wagner, D. (2020). Situated perspectives on creating mathematics tasks for peace and sustainability. *Canadian Journal of Science, Mathematics and Technology Education*, *20*, 218–229. https://doi.org/10.1007/s42330-020-00083-w

Analysing the perception of families of a virtual open school-community project on climate change

Julia Gracia, Jorge Alcántara-Manzanares, Jerónimo Torres-Porras

Faculty of Education Sciences, University of Cordoba, Spain,

e-mail: z12grorj@uco.es

1. Introduction

The key theme of the conference – Scaling-up professional development in STEM education – is one of the flagship actions of the project "Climate Change Agents (CCA)" in which our study is framed. Such a project is developed in the virtual open-school platform eTwinning, the European online collaboration platform for more than one million teachers, offering professional learning communities, peer learning and Professional Development opportunities (Vuorikari et al., 2011). eTwinning and consequently, the project CCA, foster the involvement of students, parents and teachers as a virtual open school platform. Our study analyses the perceptions of families adopting a whole school approach that promotes the positive participation of all stakeholders to address the challenges of climate change. A further aspect that links our study to the theme of the conference is that CCA included STEAM (Hoffman et al., 2021) through the integration of educational technologies, the implementation of active methodologies, and the enhancement of critical thinking. Furthermore, the project was based on climate change and integrating environmental aspects in an interdisciplinary way in the curriculum. Parents and teachers share the aim of educating children, including educating them on environmental sustainability issues. This study aims at analyzing climate change awareness amongst families from vulnerable backgrounds in Europe.

2. Methods

Our study addresses the topic of personal dimension from a specific target group as our sample applies to parents. It also adopts an international perspective as the sample (N=149) belong to parents from the Czech Republic (n=52), Greece (n=61) and Italy (n=34). Furthermore, we must highlight that the three schools are in socially deprived areas, a significant socioeconomic variable. Such a particular context will identify possible conditions for teachers and ways to approach climate change through professional development from a professional learning communities' perspective. A description of the participants, the data-collecting validated instrument used (Kuthe et al., 2019) and the descriptive non-experimental design is explained. Statistical analyses carried out including Mean and Standard Deviation, Cronbach's alpha, as well as the scale reliability per dimension, are carried out and included in tables. Kolmogorov-Smirnov's, and Kruskal-Wallis' tests results are broken down. Finally, K-means cluster analysis conducted identifies the different groups of parents and the differences between cluster centres. They are also displayed through a canonical discriminant functions image.

3. Results

The scale on its set shows a reliability according to Cronbach's Alpha statistic of 0.84. Table 1 shows the results of the mean, standard deviation, and reliability of the dimensions.

Table 1. Dimensions

Dimension	M	SD	SR
Attitude, Interest, Responsibility and Locus of Control	5,20	0.71	0.75
Personal Concern	4,04	1.40	0.96
Climate-Friendly Behaviour	4.92	0.75	0.81
M = Mean; SD = Standard Deviation; SR = Scale Reliability measured by Cronbach's alpha N = 238			

Considering the results of the Kolmogorov-Smirnov's test, we can affirm that the data do not follow a normal distribution. In the identification of the determining variables of the data model, only significant differences have been identified depending on the country, using the Kruskal-Wally's test. The Czechia has shown the lowest results in all three dimensions, and Italy the highest except in the behavioral dimension, which is behind Greece.

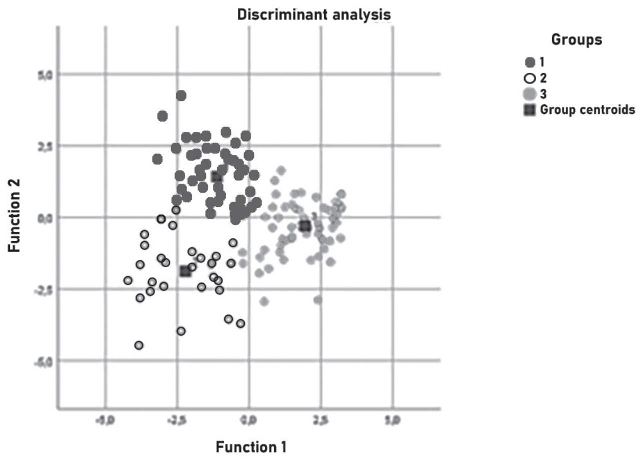
The analysis of K-means has generated with guarantees a classification in 3 groups, each with an *N* of G1 = 54, G2 = 30, and G3 = 65. There is no correlation between countries and groups generated. Table 2 shows the mean of the centroids of the groups.

Table 2. Means of the centroids of each group

	1	2	3
Attitude	5,38	4,19	5,51
Personal concern	2,90	3,22	5,36
Behaviour	5,17	3,95	5,16

The first two canonical functions of discriminant analysis explain 67.6% and 32.4% of the variance respectively. Figure 1 shows the distribution of groups in the ordering space formed by canonical functions.

Figure 1.



4. Discussion

Results show that the general level of awareness of parents in the three schools towards climate change and the open schooling project is positive with a mean score between 4 and 5 in a 6-point scale. The cluster analysis confirmed the identification of three types of parents according to their level of climate change awareness. Nevertheless, Kuthe et al. (2019) identified four types of groups with regards to students' level of climate change awareness. This information is valuable as it can help to tailor future educational open-schooling projects, rooted in a whole school approach integrating STEM, using online platforms and increasing in an intergenerational way climate change awareness. Furthermore, the findings are also relevant for identifying possible areas to scale up the professional development of teachers as well as offering directions for future studies.

Acknowledgements

We would like to thank all parents involved in this study.

References

Hoffman, L., Suh, E., & Zollman, A. (2021). What STEM teachers need to know and do to engage families of emergent multilingual students (English Language Learners). *Journal of STEM Teacher Education*, *56*(1). https://doi.org/10.30707/JSTE56.1.1624981200.199563.

Kuthe, A., Keller, L., Körfgen, A., Stötter, H., Oberrauch, A., & Höferl, K. M. (2019). How many young generations are there? – A typology of teenagers' climate change awareness in Germany and Austria. *The Journal of Environmental Education*, *50*(3), 172–182. https://doi.org/10.1080/00958964.2019.1598927

Vuorikari, R. et al. (2011). ICT-based school collaboration, teachers' networks and their opportunities for teachers' professional development - A case study on eTwinning. In H.

Leung, E. Popescu, Y. Cao, R.W.H. Lau, & W. Nejdl (Eds.), *Advances in Web-Based Learning - ICWL 2011*. *ICWL 2011*. *Lecture Notes in Computer Science*, *7048*. Springer. https://doi.org/10.1007/978-3-642-25813-8_12

CYANce: Climate Creativity – Youth for Alpine Needs establishing a sustainable co-creative climate lab and launching an "education-research-industry" network for co-creation and inquiry-based-learning in Tyrol

Elisabeth Lukasser-Vogl, Bettina Larl-Zögernitz, Vanessa Färber

Klasse!forschung, Austria

1. Introduction

The NPO klasse!forschung is a platform for non-formal STEAM education in Innsbruck, Tyrol, Austria. It unites up to 40 research organisations and enterprises ranging from universities and technical colleges, as well as innovative start-ups to well established, international industries into a network spanning from industry to research. It aims to develop and provide authentic, real-life scientific educational activities for schools and is a central hub and connecting element between schools/teachers, research organisations and companies in Tyrol.

2. CYANce

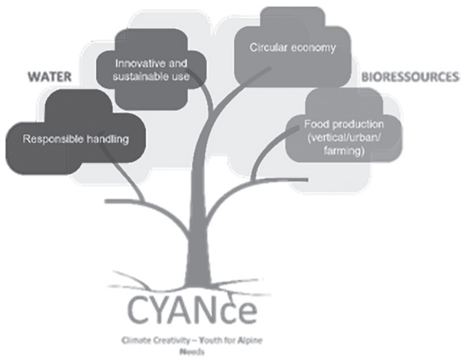


Figure 1. CYANce Tree

The project CYANce: Climate Creativity – Youth for Alpine Needs (project start: 01/12/2022) aims towards giving children and young people, from the ages of 6 to 19, an unprejudiced space to research topics and needs of the alpine habitat. The name – being a word play on science and the colour cyan as a combination of the colours blue and green – symbolises the two main research themes water (blue) and bio-resources (green).

CYANce's didactic concept (Fig. 2), partly grounded on the concept of design thinking, consists of at least seven modules that can run in different sequences but always should start with a thematic introduction (sensitise!) and should include loops of reflection.

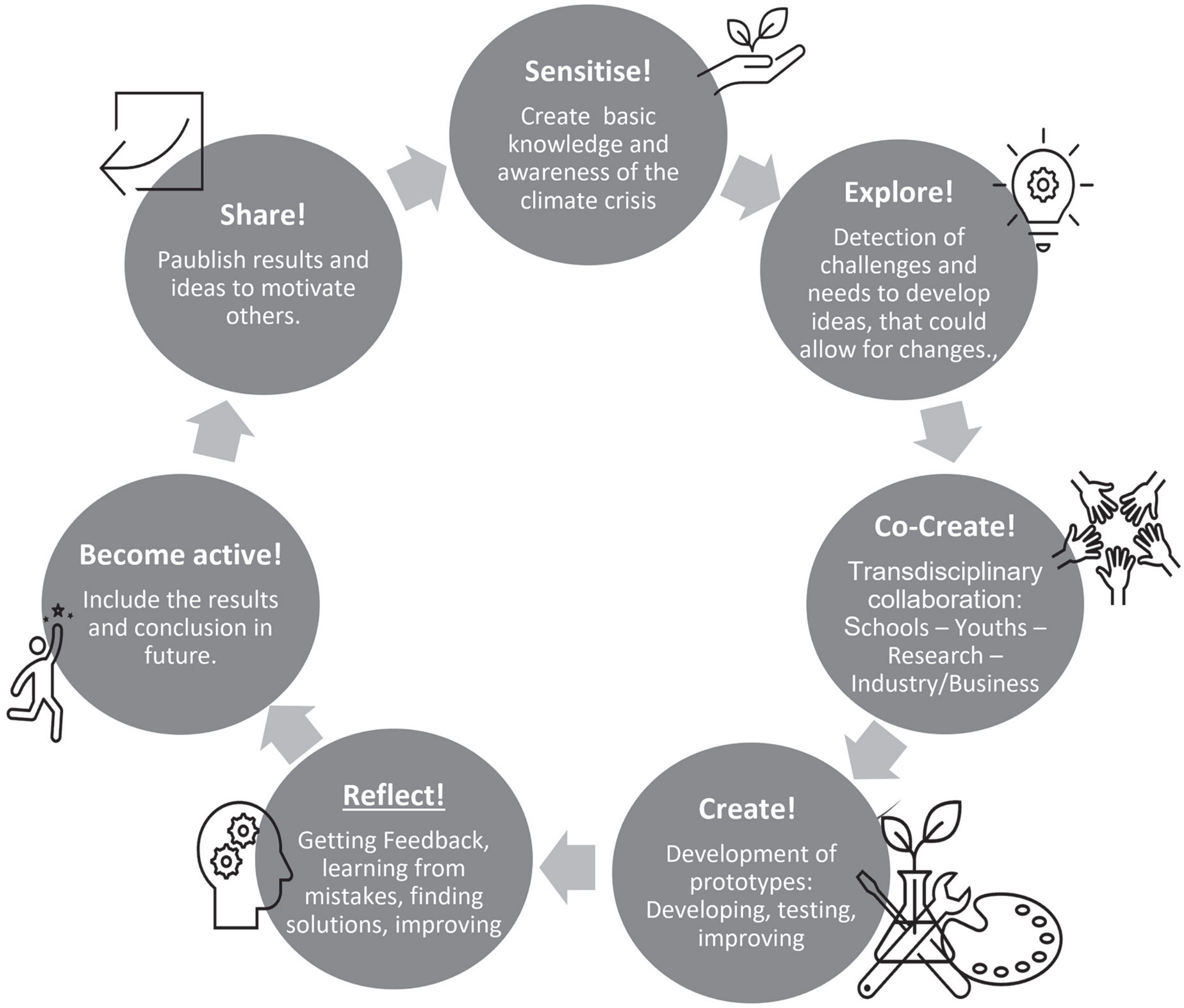


Figure 2. Didactic concept

Schools as places of learning and teaching are often limited due to various reasons; CYANce aims to break down some of those limitations and offer open-minded spaces for learning and co-creative processes.

Together with experts from science, research and industry, the kids and youths use co-creative methods to find solutions for climate protection, climate change adaptation and mitigation and the use of renewable energy resources. The main object of the project is to create and increase the awareness that the climate crisis can only be challenged by working together and through the interaction of a reflected approach, as well as the efficient use of our resources and the development of forward-looking technologies.

Through CYANce's wide, interdisciplinary partner network, the project displays the possibility to deal with a selection of topics in the context of water and bioresources in an interest-led and interdisciplinary way, following the STEAM idea. Variable infrastructure, tools and methods promote individual young talents: Biolabs in the Micromondo+ Science Center and at the universities enable a scientific approach in authentic working environments, digital fabrication labs enable an approach via technology and handicraft, participating architects, work teachers and microbiologists combine natural science with art and design and enable an approach via creative and artistic work, digital learning games enable a linguistic approach to deal with the topics and to understand interactions and control mechanisms. Variable, stationary and mobile laboratories distributed throughout Tyrol allow access even in remote regions.

Acknowledgements

This project is funded by Klima- und Energiefonds (Climate and Energy Fund Austria).

References

Heilen, L., Eberth, A., & Meyer, C. (2022). Die Bedeutung von sozialen Medien und Change Agents für Jugendliche im Kontext von Nachhaltigkeit. *In Nachhaltigkeit und Social Media* (pp. 37–57). Springer VS.

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. Journal of *Elementary Science Education*, *21*(2), 49–58.

Challenging girls to engage in STEM activities in the context of an online summer school

Eleni Kli, Giorgos Psycharis, Maria Vasilopoulou

National and Kapodistrian University of Athens, Greece

e-mail: elenikli@math.uoa.gr

Abstract

This study explores the evaluation of a STEM summer school for girls in the context of a European project aiming to bridging the gender gap for interest and competence in digital technologies. The summer school was initially planned to take place in-person by the Greek project team but due to the pandemic it was actualized in online format. The focus is on how the school was adapted to the online context as regards the pedagogic approach and the designed activities as well as on the learning outcomes for girls. Quantitative analysis of two digital questionnaires indicates positive learning outcomes for the participating girls in terms of their views about STEM and relevant professions.

Keywords

STEM education, remote teaching, online learning, summer school

1. Introduction

Digital transformation is growing and impacts many life facets. However, the lack of interest among girls to pursue studies in ICT and STEM continues to be a major problem (Kaleva et al., 2019). Even though girls and boys have similar interests and competence in digital technologies, only some girls keep on building this interest in their studies or in their careers (National Center for Education Statistics, 2012). Merging the gender gap is vital for completely incorporating the value of the digital revolution. Towards this goal, in the summer of 2021, in the framework of a European-funded program (ERASMUS +, KA2), the Greek participating team in the project (Department of Mathematics, National and Kapodistrian University of Athens) had to organise a summer school in STEM fields for girls aged 13-15 years old. Encouraging examples, role models and support to defeat stereotypes are crucial for girls and young women in recognizing that they, too, can succeed in ICT and STEM. These were our starting points for planning and designing the summer school.

As the pandemic effects and restrictions remained even during 2021, the comparative lockdown impacted more than 1.5 billion learners as teachers and students (Brunetto et al., 2022), and online education forced teachers to change how they taught (Hodges et al., 2020). In the education field, a new term, "pandemic pedagogy", has been introduced in educators' vocabulary, most of whom may have never used remote or online learning (Daymont et al., 2011; Donham et al., 2022). Emergency remote teaching, different from online teaching, which is designed to be delivered remotely, is the core option; however, when deciding to deliver online teaching, the concerns are several and diverse (Lewis & Abdul-Hamid, 2006; Edwards, Perry, & Janzen, 2011; Baran, Correia, & Thompson, 2011; Keengwe & Kidd, 2010). One of the main concerns is the quality of learning. Online learning is accused of being of lower quality compared to in-person learning (Hodges et al., 2020), although the last decade's research on online education has shown different results. Therefore, even though the initial plan was to carry out this summer school face-to-face, the restrictions forced the Greek team to deliver it online. The concerns encountered were numerous and various, such as on the level of competencies of instructors and participants in online learning, the pedagogy to be used, the transformation of activities for the online context and the role of instructors and students. Thus, two challenges were accepted: 1) How could a STEM summer school for girls be adapted to the online context regarding pedagogic approach and activities? 2) What are the learning outcomes for girls in an online STEM summer school?

2. Methodology

Before starting the planning process, specific standards common for all the summer school activities were set:

The duration of each activity: 90-minute workshops were considered as a practical timeframe, which could be either divided into 3 phases of 30 minutes or 2 of 45 minutes, if necessary, but in any case, it was assessed as sufficient time for the presentation of the relevant STEM field and cooperation between the participants.

The maximum number of participants was 20 students per activity, considered a manageable number, especially for the online format to divide them into rooms but also to have time for everyone to take the step and interact with the instructor and the rest of the participants.

Structure of content: It was decided to have a theoretical part in the activity so that all participants would have the same level of knowledge regarding the subject, but also practical application through game in an effort to combine interaction, inclusion and fun with learning and keeping the students' interest high during the activity.

During the planning of the online activities, we followed the steps below:

Step 1: we considered which STEM fields we wanted to highlight and which house object students could use for the activities. We tried to let each activity have a different STEM field because we wanted girls to have an integrated STEM experience

Step 2: we designed the activities, presented them to the rest of the group, discussed them and improved them.

Step 3: we made a list of the materials or links students will need and planned to send them by post or email to the participants' parents. We ensured they were as simple, functional and easily accessible to everyone as possible.

Considering all the above, among other activities, an example of an online activity in Biology (entitled: "Decrypting DNA") designed for a 90-minute workshop is described below. The workshop consisted of three phases. First, there was a presentation of the theory of DNA decryption by the instructor, followed by an online game in which the participants applied the knowledge of DNA decryption presented. Then, they simulated their own DNA chain according to their personal characteristics (eyes, hair, height etc.) with materials sent to them before the summer school inception. Finally, there was a session with a biochemist research scientist, who connected online from her laboratory. The lab was about pharmacological research for the diagnosis and/or therapy of various diseases. Through a virtual visit to it and to its equipment, girls could ask anything they were curious about. The scientist answered all questions, underlining the close connection between biology and chemistry.

The number of participants was kept at an average of 20, manageable for the instructor to give the floor to all participants and interact with them through discussion and questions. A combination of practice and inquiry-based pedagogy was adopted. The session was interactive, as after a small presentation by the instructor, the participating students posed questions and explored the field through creative activities and games. The instructor encouraged the girls to collaborate with peers to achieve the activity's goals. The activity combined synchronous and asynchronous communication since the students could complete the activity after the end of the online session and send photos of their creations to the instructor.

3. Results

There were many concerns about the outcome of the online version of this summer school in general but also for the specific activity. The quantitative evaluation of the overall image of the summer school showed encouraging and positive results. The summer school was assessed through the completion of a digital questionnaire by the participants before and after the summer school.

The data from the questionnaire ($N = 63$) after the summer school showed that the students enjoyed themselves and had a good time at a fairly high percentage (Figure 1).

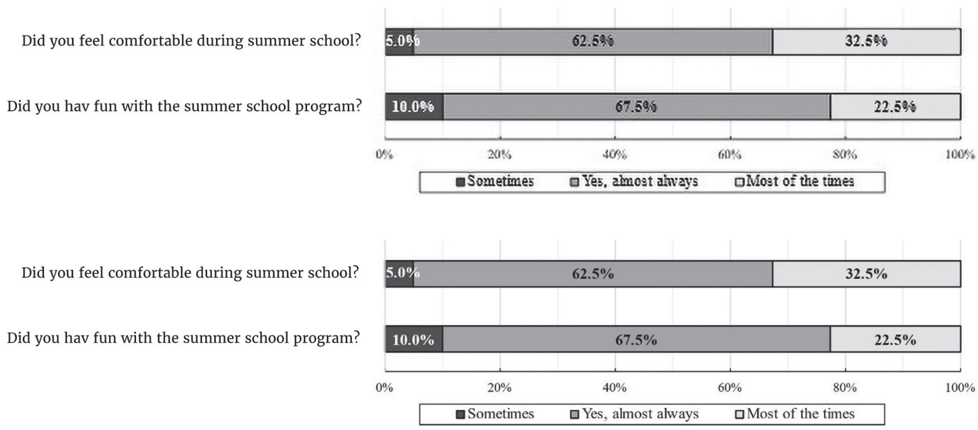


Figure 1-Perceptions of participants on their feelings during summer school

This positive reaction to an online summer school overcame our concerns about whether participants would respond and adapt to a summer school delivered remotely, given the fact that during school year just completed, classes were conducted online.

Furthermore, from Figure 2, it is evident that the summer school influenced the participating participating students in a notable proportion to start thinking differently about science in general. This reinforces the initial expectation and aspiration that girls' involvement with STEM activities could lead them closer to sciences and potentially, the eventual choice of a related profession.

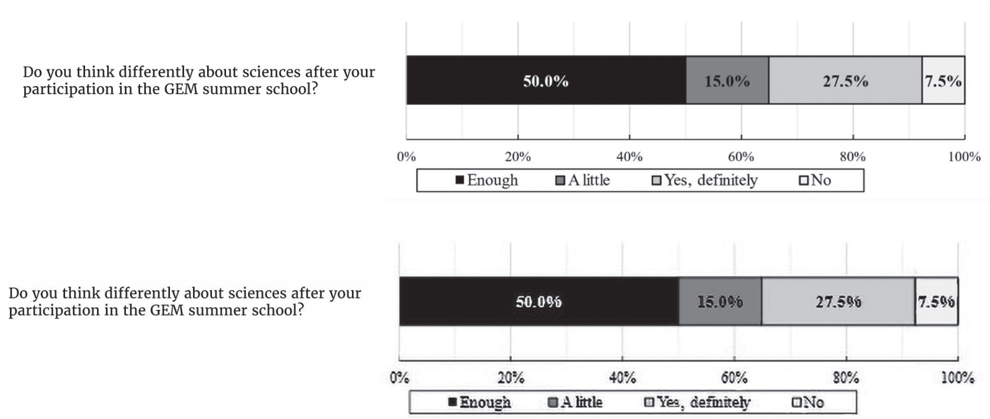
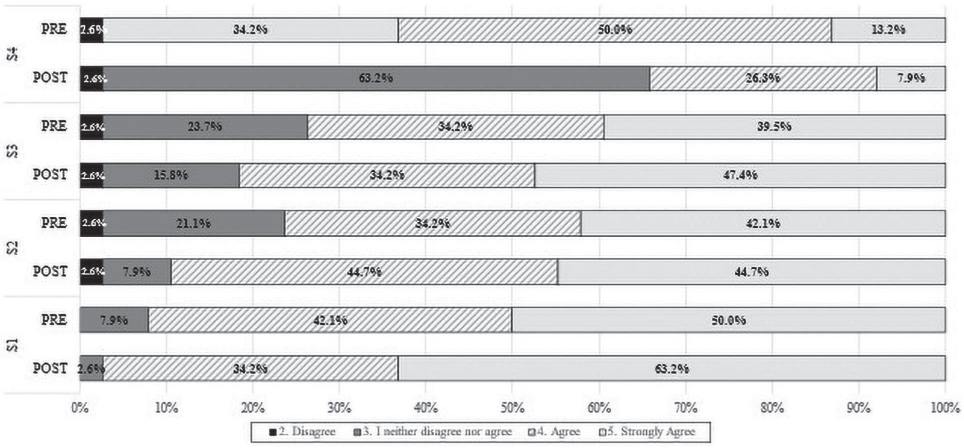


Figure 2- Question "Do you think differently about sciences after your participation in the summer school?"

This is made clearer by Figure 3, which shows the change in girls' perceptions in a remarkable percentage to certain statements before and after summer school (*N* = 38).



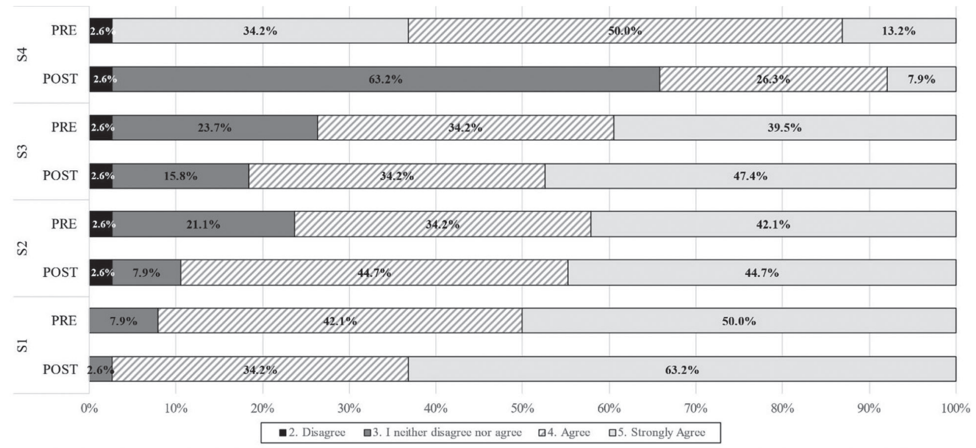


Figure 3-S1: I enjoy learning about STEM; S2: The effort I put into my STEM courses is so worthwhile because it will help me in the profession I want to follow later; S3: What I learn in STEM courses is valuable to me because I need it for what I want to study later; S4: I consider STEM easy

The qualitative results for the evaluation of the specific activity in Biology implemented online were also positive and proved that the activity operated effectively. The students were thrilled by the activity. "It was an unforgettable and unique experience. If given the chance I would participate again! […]" one of the students writes on the padlet of the activity while other points out that "I feel lucky that I was able to participate in this program. It was truly a unique and valuable experience. It provided me with a lot of knowledge and helped me understand that I am very interested in the field of Biology and Chemistry […]".

According to the instructors' views and experience of the online summer school, although they felt strange not teaching in person and pursue the most direct communication with the participants, one of them comments: "I really enjoyed the activities the girls got involved in and the interest they showed! In fact, some girls had a special talent and interest!", though other points out that: "Of course, I would prefer it to be live because a lot of girls didn't participate at all or we had a hard time identifying their needs through Webex." The instructors did not expect that the young girls would be so concerned about the stereotypes connected to girls and they were impressed how obvious this is to female students. They found out during the labs that girls were not self-confident in the activities and realized that this creates gaps.

4. Conclusion

The starting idea of this presentation was not only to show that girls can embrace STEM but also that when certain restrictions arise educators have the ability not only to adapt their teaching methods but also their teaching activities. When a STEM summer school is delivered online could have equal benefits and create equal enthusiasm to the participating students as if it was in person. The maximum of communication and interaction with students may not be achieved and the possibilities in the implementation of some activities may seem limited, but the benefits and positive points are evident. On the one hand, it enhances and encourages the development of digital skills, and, on the other hand, it allows for autonomy and flexibility of participation from different parts of the country, as in the case of the Greek summer school, for both participants and educators. It is essential, when planning and designing the activities, to consider that it will be performed online, in order to use the appropriate tools to achieve the combination of pedagogies and to better describe the role of the educator in achieving effective STEM education.

References

Baran, E., Correia, A., & Thompson, A. D. (2011). *Paths to Exemplary Online Teaching: A Look at Teacher Roles, Competencies and Exemplary Online Teaching.* Education.

Brunetto, D., Berbardi, G., Andra, C., & Liljedahl , P. (2022). Teaching as a system: COVID-19 as a lens into teacher change. *Educational Studies in Mathematics*, *110*, 65–81.

Daymont, T. N., Blau, G., & Campbell, D. (2011). Deciding Between Traditional and Online Formats: Exploring the Role of Learning Advantages, Flexibility, and Compensatory Adaptation. *Journal of Behavioral and Applied Management*, *12*(2), 156.

Donham, C., Barron, H. A., Alkhouri, J., Kumarath, M., Wesley , A., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic. *International Journal of STEM education*, *9*(19).

Edwards, M. J., Perry, B., & Janzen, K. J. (2011). The making of an exemplary online educator. *Distance Education*, *32*, 101–118.

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The diference between emergency remote teaching and online learning. *Educause Review*, *27*, 1–12.

Kaleva, S., Poursiainen, J., Hakola, M., Rusanen, J., & Muukkonen, H. (2019). Students' reasons for STEM choices and the relationship of mathematics choice to university admission. *International Journal of STEM Education*, *6*(43). doi.org/10.1186/s40594-019-0196-x

Keengwe, J., & Kidd, T. T. (2010). Towards best practices in online learning and teaching in higher education. *Education. MERLOT Journal of Online Learning and Teaching*, *6*(2).

Lewis, C., & Abdul-Hamid, H. (2006). Implementing effective online teaching practices: Voices of Eexemplary faculty. *Innovative Higher Education*, *31*, 83–98.

National Center for Education Statistics. (2012). *Degrees conferred by degree-granting institutions*. Washington, DC. Retrieved from http://nces.ed.gov/programs/digest/d12/tables/dt12_318.asp

Context-based teaching for students' sustainability consciousness

Hanne Valde Thu[1], Ragnhild Lyngved Staberg[2], Maria Febri[2], John Magne Grindeland[2], Jan Tore Malmo[2]

[1] *Akademiet lower secondary school, Lier, Norway*

[2] *Norwegian university of science and technology, Department of teacher education, Trondheim, Norway*

e-mail: hanne.thu@akademiet.no

1. Introduction

This presentation relates to Topic 2 (Material dimension) and addresses the question: "What materials do teachers need to run open schooling projects?" Our study is conducted within the context of the Horizon 2020 project MOST (Meaningful Open Schooling Connects Schools to Communities), which intends to open up school education by initiating school-community projects (SCPs) across Europe. Within a school-community-project, schools and community members work together to find regionally implementable and scientific approaches to sustainable issues. The focus in this paper is on waste management, more specifically, we follow a 5th grade class in Norway when exploring chewing gum waste in their local context and investigate the importance of context-based teaching on students' sustainability consciousness.

As teacher educators within the MOST project, we have developed an SCP manual and SCP pedagogical guidelines for in-service and pre-service teachers. Our aim is twofold: Firstly, to equip future science teachers with knowledge about open schooling and competencies in teaching using this approach. Secondly, by working with prospective teachers, we hope they will continue implementing SCPs in their day-to-day science teaching once they finish their education. Thus, we aim at spreading the materials at national level. The SCP-materials developed in MOST is meant to be used by teachers and teacher educators, hence the relevance to the overall conference theme (Educating the Educators) and to Topic 2. Our presentation will be addressed from a target group-specific perspective, i.e., primary students' outcomes. We intend to use the oral presentation format.

2. Theoretical background and rationale

Context-based teaching is often highlighted as a means for students to experience the teaching as relevant and close to reality (Gabrielsen & Korsager, 2018; Sinnes, 2020). Context-based teaching uses authentic learning contexts as a starting point for learning. This study is based on an authentic context from the students' everyday life and uses this context as a starting point for learning about sustainable development (SD).

SD has been promoted in Norwegian school for a long time (e.g., curricula from 1922, M74, L97, LK06). With the new curriculum from 2020, SD was introduced as an interdisciplinary topic in all subjects (Kunnskapsdepartementet, 2017). Although SD is not a new concept, there is little research on the implementation and prioritization of SD in schools (Boeve-de Pauw et al., 2015; Sinnes and Straume, 2017; Bjønnes & Sinnes, 2019). Smaller investigations may indicate that even if SD has been part of school for a long time it has not been prioritized, and the focus has been on students' theoretical understanding of the subject (Bjønnes & Sinnes, 2019). Focus on the theoretical understanding of environmental and climate challenges in schools can lead to students being overwhelmed and paralyzed (Hicks & Bord, 2001). Although many young people show an interest in and have knowledge of these global problems, it is common to feel frustration, fear for the future and to feel helpless (Ojala, 2012). It has therefore been argued not only to teach about challenges we face, but also convey success stories and show students that they can make a difference. It is then important that students develop action competence to ensure that SD becomes part of their everyday life (Olsson et al., 2016; Scheie & Korsager, 2014).

The concept sustainability consciousness is closely linked to Breiting and Mogensen's (1999) definition on action competence; knowledge of possible action alternatives, belief in one's own ability to influence and willingness to act (Olsson et al., 2016). The term is intended to reflect students' action competence within each dimension of SD and therefore implies knowledge (K), attitudes (H) and actions (H) within the environment and climate, economy and social conditions. Sustainability consciousness involves a more holistic approach to SD than action competence as it includes both cognitive, affective and knowledge-based components (Olsson et al., 2016). In this study we lean on Gericke et al.'s (2019) operationalization of the concept of sustainability consciousness that includes knowledge, attitudes and behaviors within the three dimensions of SD.

The research question guiding this proposal is: How can context-based teaching influence students' sustainability consciousness? The sub-questions are:

1. How have students' knowledge, attitudes and behaviors changed as a result of implementation of a context-based teaching unit?
2. How do students experience working with a context-based teaching unit which aims to influence their sustainability consciousness?

3. Context: Description of the implemented SCP

The teaching unit was designed based on MOST SCP Pedagogical principles: 1) Features of SCP ways of working: Student-centered, collaborative, dialogic and interactive, respectful, value mistakes as learning opportunity, multi perspective approach of problem, attentive to girls' interest and motivation, 2) Features of SCP problems: Authentic and co-created, shared ownership, motivation, environmental related Socio Scientific Issues (SSI), meaningful and relevant, scientific or technological strategies required. The SCP, which lasted for about one month, started with an excursion to the local city center where students had to look for problems. The students then decided which problem they would like to learn more about and find a solution to. This coincides well with Sinnes's model (2020) where the goal is to develop hope and find solutions to the problem. The class decided to work with chewing gum which is thrown on the ground. They explored the topic of chewing gum, why it is a problem, and what can be done to solve the problem and decided that separate bins for chewing gum could be a good solution. Family members, citizens, researchers and municipality members were involved.

4. Materials and methods

The study design is of a mixed method approach including a pre-post student questionnaire (N=17), and a focus group interview with a small sample of students (N=3). The questionnaire focused on three indexes of sustainability consciousness: knowingness, attitudes and behaviors, inspired by Gericke et al. (2019). The results were analyzed using descriptive statistics.

Of those who completed the survey, students were selected via opportunity sampling to take part in a focus group semi-structured interview. During the interview, they were asked to elaborate on their own sustainability consciousness (knowledge of the possible action options, believe in their own ability to influence, willingness to act), and their experiences of working with the context-based project. Interviews were subject to thematic analysis (Braun & Clarke, 2006). Students were in the 5th Grade, 10-11 years old.

5. Results and discussion

The results from our study show no statistically significant change in the students' sustainability consciousness after completion of the context-based project. Descriptive statistics from the analysis of the pre-and post-tests show a slight decrease in students' knowledge and attitudes. The students' attitudes were characterized by seriousness and concern. It might be that the lessons to a large extend focused on challenges and developing students' knowledge of the problem. As Hicks and Bord (2001) show, a too high focus on the theoretical understanding leads to students being overwhelmed and paralyzed by action. In the interview it emerged that the students had a lot of knowledge about SD, but it seemed that the students directed their focus towards everything they did not know. This may indicate that the students have gained more knowledge and became more aware of how extensive and complex issues related to SD are. The tendency to decrease in students' attitudes can also be explained by the fact that the students' proposals for solutions were not taken seriously by the municipality, leading to the feeling that they did not have real influence.

Results from the thematic analysis of the focus group interview indicate that the students themselves believe that they, and people in general, lack knowledge about the subject in question, and as a consequence they express concern about sustainability issues, as expressed by one of the students: "It was kind of interesting for me when I saw how many people came to our exhibit point, where we showed many people [what we did]. They didn't know much, and lots of people came. Even our parents didn't know. And if that many people didn't know [about the problem] then, what does the world know?" On the other hand, the students express a desire to make a change and express that they need to be given the opportunity to do so: "We can make a difference if we are given the opportunity to". The students contacted the local municipality and suggested solutions to how the problem can be solved, but they were demotivated by not getting a good enough response from the municipality: "We spoke to the municipality, but we didn't get much. We had a meeting with them halfway through and then they said, "we will take it into account", and then we will see what happens and we haven't heard back from them". They experienced that they were not given the opportunity to contribute and felt that they were not heard. It emerged that they were worried about the future and believed that people in power, such as politicians, were not doing enough to promote SD.

Regarding behaviour, there is a slightly positive trend, where the students have become more neutral to the questions about actions. In the interview, the students conveyed that their habits, associated with chewing gum, had changed. It also emerged that the students enjoyed both the working methods and the content of the teaching unit. When it came to measures that can be taken to contribute to SD, the students had many suggestions, mainly linked to changes in own consumption habits.

Despite the limited number of participating students in our study, the limited time frame for the project and non-significant results, we would argue that context-based teaching can have a positive effect on students' sustainability consciousness if the focus is on solutions to problems that are taken from the students' immediate environment, so that students experience personal relevance and are able to influence decisions regarding their own lives.

Acknowledgements

This proposal is based on work within the project Meaningful Open Schooling Connects Schools to Communities (MOST), which has been co-funded by the Horizon 2020 programme of the European Union under grant agreement n° 871155. We appreciate the effort of students that participated in the survey and interview and the financial support from our Department at Norwegian University of Science and Technology.

References

Bjønnes, B., & Sinnes, A. T. (2019). Hva hemmer og fremmer arbeidet med Utdanning for Bærekraftig Utvikling i videregående skole? *Acta Didactica Norge*, *13*(2). dx.doi.org/10.5617/adno.6474

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. doi.org/10.1191/1478088706qp063oa

Breiting, S., & Mogensen, F. (1999). Action competence and dnvironmental dducation. *Cambridge Journal of Education*, *29*(3), 349–353. doi.org/10.1080/0305764990290305

Boeve-de Pauw, J., Gericke, N., Olsson, D., & Berglund, T. (2015). The effectiveness of education for sustainable development. *Sustainability*, 7(11), 15693–15717. doi.org/10.3390/su71115693

Gabrielsen, A., & Korsager, M. (2018). Nærmiljø som læringsarena i undervisning for bærekraftig utvikling. En analyse av læreres erfaringer og refleksjoner. *NorDiNa*, *14*(4), 335–349. doi.org/10.5617/nordina.4442

Gericke, N., Boeve-de Pauw, J., Berglund, T., & Olsson, D. (2019). The sustainability consciousness questionnaire: The theoretical development and empirical validation of an evaluation instrument for stakeholders working with sustainable development. *Sustainable Development (Bradford, West Yorkshire, England)*, *27*(1), 35–49. doi.org/10.1002/sd.1859

Hicks, D., & Bord, A. (2001). Learning about global issues: Why most educators only make things worse. *Environmental Education Research*, *7*(4), 413–425. doi.org/10.1080/13504620120081287

Kunnskapsdepartementet (2017). *Overordnet del- verdier og prinsipper for grunnopplæringen*. https://www.regjeringen.no/contentassets/53d21ea2bc3a4202b86b83cfe82da93e/overordnet-del---verdier-og-prinsipper-for-grunnopplaringen.pdf

Ojala, M. (2012). Hope and climate change: the importance of hope for environmental engagement among young people. *Environmental Education Research*, *18*(5), 625–642. doi.org/10.1080/13504622.2011.637157

Olsson, D., Gericke, N., & Chang Rundgren, S.-N. (2016). The effect of implementation of education for sustainable development in Swedish compulsory schools – assessing pupils' sustainability consciousness. *Environmental Education Research*, 22(2), 176–202. doi.org/10.1080/13504622.2015.1005057

Scheie, E., & Korsager, M. (2014). Utdanning og undervisning for bærekraftig utvikling. *Naturfag*, *2*, 18–21.

Sinnes, A.T. (2020). *Action takk! Hva kan skolen lære av unge menneskers handlinger for bærekraftig utvikling*? Gyldendal.

Sinnes, A.T., & Straume, I. S. (2017). Bærekraftig utvikling, tverrfaglighet og dybdelæring: fra big ideas til store spørsmål. *Acta Didactica Norge*, *11*(3).

Changes of components of reflection and practice of novice facilitator in context of co-designing mathematical trails

Janka Medová, Silvia Haringová

Constantine the Philosopher University in Nitra, Faculty of Natural Sciences and Informatics, Department of Mathematics, Nitra, Slovakia

e-mail: jmedova@ukf.sk

Despite the recommendations of national curricula and several years of support, transmissive classes seem to be prevalent in Slovakia. Most teachers do not have experience with posing and solving open modelling problems. Mathematical trails seem to provide reasonable activity for students where they spend time outside by solving mathematical problems related to real objects (Čeretková & Bulková 2020). Posing problems related to real objects allows designing the problems dealing with socio-scientific and environmental issues.

MathCityMap is a system for designing and enacting math trails with the support of technologies (Barlovits & Ludwig 2020). Collaborative designing and enacting of mathematical trails offer various affordances in professional development of in-service as well as pre-service teachers (Haringová & Medová, 2022), e.g., during the planning teachers pose and formulate new problems related to social-scientific issues, formulate hints in order to provide scaffolding for their students; during the implementation of trail teachers observe their students during problem-solving. The involvement in co-design put special requirement also on the teacher educators.

Methodology

In this self-study, we identify opportunities to learn and changes in various aspects of work of professional development of novice facilitator. Silvia (the second author of the paper) started to work with MathCityMap trail when she was in year 3 of her initial teacher education. She got very excited by the idea and dedicated her master thesis to posing problems with MathCityMap and their enactment out-doors and in remote conditions caused by measures related to Covid-19 pandemics. Just after finishing her master's degree in mathematics and informatics education, she did not become a teacher but applied for and was accepted for doctoral studies in mathematics education.

In order to describe the changes in the various aspects of Silvia resources, goals and orientations we used the double level framework by Karsenty (2020). Deductive analysis of the transcripts of the webinar was used. Each of the sentences was categorised using the Six Lense Framework to enable accessing changes in Silvia's identity as a teacher and Meta-Lences Framework in her identity as professional development facilitator.

Results

Her thesis should be focused on co-design of materials for inquiry-based classrooms. As she was so keen on MathCityMap trails, she adopted the lesson study model to work with teachers on posing problems, designing the MathCityMap trail, enacting the trails and reflect on the activities. Silvia has supervised more than 15 MathCityMap trails with teachers around Slovakia and led several workshops about designing the MathCityMap trails in Czech Republic and Slovakia. She was actively involved as supervisor of students during solving the tasks in MCM trails, so she gained also an experience as a teacher in this settings. Each activity for teachers was followed by a mentoring session with her supervisor.

There were two webinars led by Silvia. One was organised during last months of her master study by the institution providing the professional development for in-service teachers in April 2021. The second webinar was held in October 2022 after all the mentioned activities and was organised by the Department of Mathematics. According to enactivist paradigm "knowing is doing and doing is knowing" (e.g., Brown & Coles, 2011) we can observe the development of novice PD facilitator based on her enactment of the two webinars. Her developed expertise should be observable in this action.

The most obvious change was in the number of sentences addressed directly to the attending teachers. She expressed here goals as a facilitator more explicitly. In her journal she reflected on her perception of the two webinars as follows "we want to take students outdoor and show them how they can use mathematics in the real-life world, because mathematics is all around us".

During posing and enacting the MathCityMap trails Silvia got the knowledge and experience not only with work with teachers, but as an unexperienced teacher also with work with pupils. It influenced the PD agenda and ideas, as the focus of the first webinar was on the technological particularities of the MathCityMap portal, whereas during the second webinar the pupils' behaviour and experiences with enacting the trails were addressed.

Acknowledgements

The publication is (partially) funded by the Ministry of education, science, research and sport of the Slovak Republic under grant no. KEGA 015UKF-4/2021 and by Slovak Research and Development Agency under grant no. APVV-20-0599.

References

Barlovits, S., & Ludwig, M. (2020). Mobile-supported outdoor learning in math class: Draft of an efficacy study about the MathCityMap app. *Research on Outdoor STEM Education in the digiTal Age*, (pp. 55–62). WTM.

Brown, L., & Coles, A. (2011). Developing expertise: how enactivism re-frames mathematics teacher development, *ZDM*, *43*(6), 861–873.

Čeretková, S., & Bulková, K. (2020). Mathematics trails in initial teachers education in Slovakia. *APLIMAT 2020*, 232–237.

Haringová, S., & Medová, J. (2022). Math trails supporting the collaboration between mathematics teachers in professional development. *Twelfth Congress of the European Society for Research in Mathematics Education (CERME12),* Feb 2022, Bozen-Bolzano, Italy. hal-03744253

Karsenty, R. (2020). The role of frameworks in researching knowledge and practices of mathematics teachers and teacher educators. *Professional development and knowledge of mathematics teachers*, (pp. 62–84). Routledge.

Development of STEM education in KUSH: Task design for inquiry-based learning through Lesson Study

Minoru Ohtani

Kanazawa University, Japan

e-mail: mohtani@ed.kanazawa-u.ac.jp

Abstract

This study aims at developing STEM oriented Inquiry-Based Learning at a Japanese high school through a modified Lesson Study approach. The author collaborated with teachers of the mathematics department of Kanazawa University Senior High School to design a task of "simulating spread of Covid-19 infection" for a Research Lesson. In post-collaborative reflections on Research Lesson, we invited selected three students to incorporating the learner's perspective as a key topic of discussion. This modification enables teacher and participants to access learners' actual inquiry processes while they engage the simulation tasks.

Keywords

STEM education, inquiry-based learning, lesson study, learner's perspective

1. Purpose of the Study

There is growing interest in developing the qualities and abilities to think mathematically in realistic situations through the process of inquiry. In addition, efforts are being made to make appropriate use of ICT in mathematics classes. Department of mathematics at KUSH is promoting research in collaboration with university teaching staff, referring to the Dutch idea of 'realistic mathematics education' (Van den Heuvel-Panhuizen & Drijvers, 2014) and is working on inquiry-based, collaborative, and cross-curricular STEM education. The author collaborated with teachers of the mathematics department of Kanazawa University Senior High School (KUSH) to design STEM related task sequence on "simulating spread of Covid-19 infection" as material for Research Lesson (RL) in Lesson Study (LS) (Otani, 2021). We designed a task simulating the spread of Covid-19 infectious diseases with a simulation based on the assignment in the "Mathematics A" of National Examination (Cito, 2003). At the end of 2020, in Japan, the spread had just begun in February on the Diamond Princess cruise ship and the spread became an authentic social issue. This presentation consists of three Japanese LS processes: collaborative task design for a RL, implementation of the task in the RL, and three students' perspectives on the task and their mathematical activity post the collaborative RL that included participants (Fujii, 2016).

2. Task Design for Research Lesson

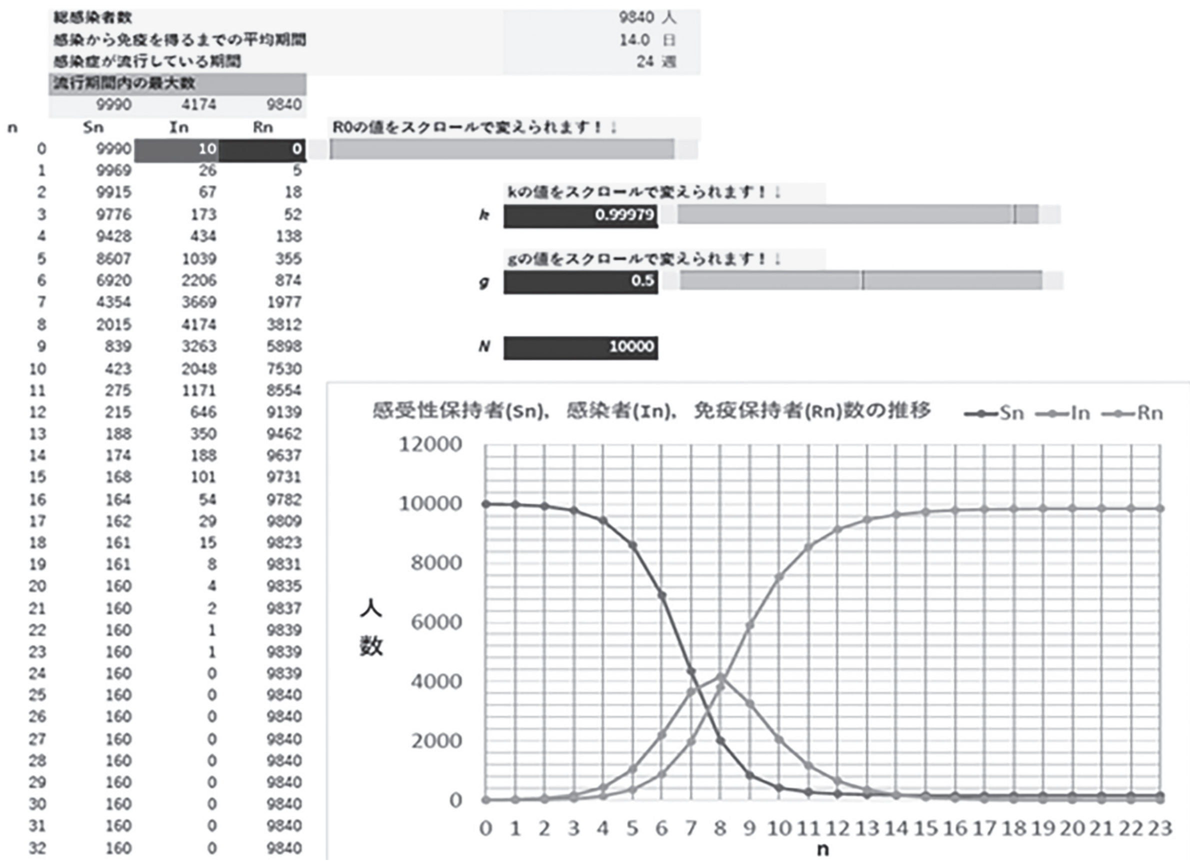
We designed a task for grade 12 (second year) of high school. We located the task in the third subunit "limits of sequences" (3 class hours) of unit "Functions and Limits". The subunit consists of "mathematical models of infectious diseases", "simulation of infectious diseases" (RL), and "simulation of various infectious diseases". The mathematical model of infectious diseases is represented by analytically unsolvable systems of recurrence formulae and requires the concept 'limit of sequence'. The number of infected and cured persons after a sufficient period can be estimated, so it was considered appropriate as a task for this subunit. In addition, simulation with ICT is suitable for the analytically unsolvable equation.

We adopt the Reef-Frost model with a population of *N* persons, Week 0 is the week when the first infected person appears. *Sn*, *In*, and *Rn* represent respectively the number of susceptible persons, the number of infected persons, and the number of immune persons after n weeks, where the following conditions are assumed to hold: (i) only those who are currently infected have the ability to infect susceptible persons, (ii) infected persons are cured and immune after one week, and (iii) immune persons will not be infected again. The following relation (*) holds.

Figure 1 shows simulation result with *N* = 10000, *k* = 0.99979 and 10 people are infected in week 0. The Excel sheet shows a graphic distributions of *Sn*, *In*, and *Rn* as well as total number of Infected persons (9849), the average days to recover (14 days), duration of epidermis (24 weeks), and maxmal numbers of Sn (9990), In (4174), and Rn (9840) during the epidemics.

We designed three tasks based on these conditions. Task 1: To simulate infectious diseases (*) and the effects of vaccination upon these is modelled using an Excel sheet. We expect students to be familiar with it and to share their results. Task 2: The model from Task 1 is modified to make it more realistic. Infections no longer satisfy the conditions that more than one week is required for cure and immunity always occurs after infection. It is assumed that a certain proportion g (0<g≤ 1) of infected persons are cured in the week following infection represented by the modified model (**).

$$\begin{cases} I_{n+1} = (1 - k^{I_n}) \cdot S_n \\ R_{n+1} = R_n + I_n \qquad \cdots \quad (*) \\ S_{n+1} = N - I_{n+1} - R_{n+1} \end{cases}$$



n	Sn	In	Rn
0	9990	10	0
1	9969	26	5
2	9915	67	18
3	9776	173	52
4	9428	434	138
5	8607	1039	355
6	6920	2206	874
7	4354	3669	1977
8	2015	4174	3812
9	839	3263	5898
10	423	2048	7530
11	275	1171	8554
12	215	646	9139
13	188	350	9462
14	174	188	9637
15	168	101	9731
16	164	54	9782
17	162	29	9809
18	161	15	9823
19	161	8	9831
20	160	4	9835
21	160	2	9837
22	160	1	9839
23	160	1	9839
24	160	0	9839
25	160	0	9840
26	160	0	9840
27	160	0	9840
28	160	0	9840
29	160	0	9840
30	160	0	9840
31	160	0	9840
32	160	0	9840

Figure 1 Excel sheet for Task 1 (N = 10000, k = 0.9979, In = 10)

Task 3: What changes occur in the simulation results when the values of the various constants are varied? Communicate your results. Task 3 is intended to make the students aware that a smaller value of the constant g can lead to 'bad' infections, including some where there is an increase in the number of infections. We expect R0 has the effect of substantially reducing N, and that if N is increased while k is fixed, the infection spreads quickly where k is a measure of the 'strength' of the infection in a population of N people, and $0 \leq k \leq 1$ (the smaller k, the stronger the infection. In task3, the students simulated the model (**) in groups by changing the values of I0, R0, k, g and N, and described what they felt, thought, understood and did not understand.

In the end of the RL, the teacher showed an additional model for further inquity as homework assignment in which diseases do not develop immunity. In such diseases, In = 0 for all n. Some cured people quickly become susceptible and become ill again. If we assume that we are cured in one week of treatment (g=1), we obtain the following simultaneous recursive equations (***).

$$\begin{cases} I_{n+1} = (1 - k^{I_n}) \cdot S_n + (1 - g) \cdot I_n \\ R_{n+1} = R_n + g \cdot I_n \qquad \cdots\cdots \ (**) \\ S_{n+1} = N - I_{n+1} - R_{n+1} \end{cases}$$

3. RL and Students' Perspectives of the RL

RL was implemented in a class of 44 students on 22 February 2020 with 27 visiting participants. Students worked in groups of four, and each group was given 12 laptop computers, but we also encouraged the use of personal computers and mobile terminals (Fig. 3). During the RL, participants walked between students' desks and made observations and took fieldnotes concerning students inquiry processes, their written artifacts and interaction among peers so as to make use of post lesson collective reflection.

The lesson consisted of an introduction (5 minutes), task 1 (12 minutes), task 2 (10 minutes), and task 3 (18 minutes) and a summary (5 minutes). In the introduction teacher Sakai reviewed the data of the cruise ship and the Reed-Frost model (*). Activities for the three tasks went as planned.

Collective post RL reflection and discussion are one of feathers of the Japanese LS approach. Since only teacher of RL and participants attend post RL reflection, main topic of discussion consists in teacher's perspectives of both intended and implemented RL. However, actual learner's perspective is still underrepresented. In post collaborative reflections on Research Lesson, we invited selected three students so as to incorporating learner's perspective as key topic of discussion. This modification enables teacher and participants to access learner's actual inquiry processes while they engage the simulation tasks. The research collaborator selected three students (A, B, and C) based on the activities he observed in RL and his opportunities to listen to their ideas (Fig. 4). In the picture, facilitator, teacher, notetaker, and research collaborator sit in front desk from left to right and three invited students sit besides the research collaboratior.

Figure 3 RLesson with participants

Figure 4 Post RL reflection with students

Among many reflections, there were three topics regarding students' perspectives.

(1) What is your overall impression of the lesson? Student A said, "It was more realistic than usual, and I wanted to think about how the equation fits with the actual graphs of infectious diseases in the world, which have been talked about on TV and other media recently". Student B replied, "I had vaguely thought that the number of infectious diseases had been increasing in the recent news, but

it was good to understand the actual relationship between multiple quantities". Student C commented, "It was interesting to see how a slight change in one value could drastically change the other values. It was also good to exchange opinions on the relationship between variables".

(2) Wat were you thinking while working on task 3? Student A said, "I changed the value of one of the variables because it was difficult to know how many values there were. I paid most attention to what would happen to the graph if I changed the value, not to what I wanted to do with this value". Student B said, "my group had fun working on it, we wanted to make sure that the number of people infected was all of them, and we used a lot of vaccine so that no one got infected. I should have thought more about being realistic." Student C said, "we tried to make *n* bigger, and we often found that everyone was infected, which is not the case in the real world, and when that happened, we thought about what was wrong with this model."

(3) When asked what they would like to simulate more? Student A said, "this time the value of *k* is the vaguest, I would like to simulate the actual number of people we encounter in a day, or how many people would be affected if one person contracted the disease at school." Student B said, "infectious diseases are actually more complicated and I don't think they can be expressed in three equations". Student C said, "I am similar, but I think there are factors that we have to consider in practice, but I want to think about how we can bring it closer to reality."

4. Concluding Remarks: Lessons from LS

The 'Learner's Perspective Study' (Clarke et.al, 2013) elaborated seminal research methodology on learner's perspective while participating in mathematics lessons. This study combined the learner's perspective with LS processes to establish wider stakeholder approach.

Presence of students in post collaborative reflections on RL changed the discourse of participants and students' perspectives became a key topic of discussion. Such slight modification of Lesson Study ritual enabled teacher and participants to access learner's actual inquiry processes while they engage the simulation tasks. From the students' replies, they faced considerable difficulties with managing 3 or 4 multi-variable asymptotic formulas for which there is no closed-form solution. With teacher's guidance and suggestions, there were diverse approaches in students' systematic search in view of their interest in peculiar phenomena. Students sometimes question the authenticity of models and showed interest in the difference between models and real phenomena. We have to take into account such students' perspectives while designing task sequence for STEM related Inquiry-Based Learning.

Incorporating the students' perspective in post RL reflection enables us to bridge all stakeholder's perspectives: voices of RL teacher, participants, and learners. However, at the ETE V paper presentation session, one of the participants gave insightful suggestion that it might be more relevant to give an opportunity for the students to ask teacher and participants so as to establish authentic stakeholder approach in LS.

Reference

Cito (2003). *Epidemies. Examen VWO–compex. Wiskunde A 1,2* (nieuwe stijl). Retrieved from: https://www.examenblad.nl/.

Clarke, D. J., Keitel, C., & Shimizu, Y. (Eds.), (2013). *Mathematics classrooms in twelve countries: The insider's perspective*. Sense Publishers.

Fujii, T. (2016). Designing and adapting tasks in lesson planning: a critical process of Lesson Study. *ZDM Mathematics Education*, *48*, 411–423.

Ohtani, M. (2021). Designing problem-exploratory lessons in mathematics departments of senior high schools: A case study of infectious disease tasks. In *Proceedings of the 54th Autumn Conference of the Japan Society for Mathematics Education*, 185–188. (in Japanese)

Van den Heuvel-Panhuizen, M. & Drijvers, P. (2014). Realistic Mathematics Education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 521–525). Springer.

Educating the educators: An innovative M.Ed. program in integrative STEM education incorporating open schooling principles

Noa Ragonis, Daphne Goldman, Osnat Dagan

Beit Berl College, Israel

e-mail: noarag@beitberl.ac.il

Abstract

This paper introduces an M.Ed. program in 'Integrative STEM Education', preparing teachers to incorporate innovative teaching approaches. The program adopts Open Schooling principles, emphasizing collaboration, real-life projects, and sustainability. The curriculum promotes student-centered learning around authentic multidisciplinary challenges. The paper discusses two courses that exemplify how OS principles are implemented and presents preliminary findings supporting the program's impact in preparing teachers as change agents.

Keywords

integrative STEM education, open schooling, sustainability education, M.Ed., teacher education

1. Framing the challenge

Contemporary society is characterized by the rapid development of information, science, and technology, and an increased understanding that citizens are confronted daily with complex challenges requiring a holistic transdisciplinary problem-solving perspective and multi-level competencies (Bybee, 2013). Teachers, as key actors in responding to this challenge, need to develop their knowledge, skills, and practices to incorporate cutting-edge teaching, learning, and evaluation approaches into their classes and schools. To meet this challenge, an innovative M.Ed. program called 'Integrative STEM Education' was developed at Beit Berl College, Israel. The program seeks to serve as a living lab for students that have an academic background in one of the STEM disciplines, experience in teaching, and may have a background working in industry. In view of the central role environmental and sustainability issues play in the 21st century world, and the inherent interdisciplinarity of these complex issues, the program anchors several of the courses and learning activities in this context. Additionally, as the responsibility for educating the next generation lies not only with the school system but is a challenge and responsibility of our whole society, the program implements several principles of Open Schooling (OS), specifically cooperation with various societal stakeholders. Professionals from industry, academia, enterprise, civil society and wider society are actively involved in bringing real-life projects into the program. Through this, the program implements the OS approach, by which STEM-oriented learning processes are linked to the students' engagement in real-life science, engineering, and ethical challenges confronting society, research, employment, and education. Teachers graduating from this program are equipped to develop their pupils' perceptions, personal identity, values, and competencies based on interacting with authentic multidisciplinary challenges, and to increase their pupils' motivation for engaging with STEM.

2. Theoretical framework – Open Schooling approach for Responsible Citizenship

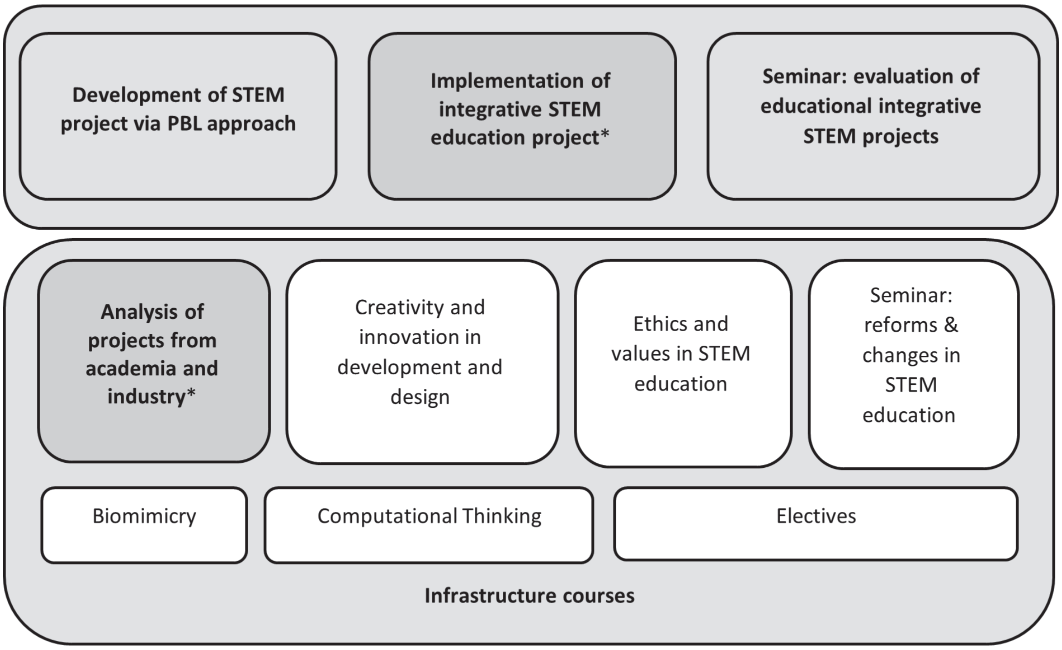
There are different approaches to the notion of Open Schooling, for example, open schooling in developing countries targets the challenge of increasing access to basic education (Phillips, 2006). We adopt the approach of the European Union that addresses the role of science for society, by which Open Schooling is identified as a means for promoting meaningful science education by connecting science to the real world of the learners. This approach acknowledges that science education is a crucial component of broader educational goals to prepare engaged and responsible citizens and a workforce equipped with the competencies for the complex challenges of life and work in the 21st century (Hazelkorn et al., 2015). In line with this conceptualization of OS, several attributes are targeted for open schools (i.e., schools that open themselves to the community). These are briefly outlined in the following: (a) Collaboration with local non- and in-formal education centers, enterprises, families, and civil society. Collaborative learning with local professional practitioners can contribute to meaningful and relevant engagement in socio-scientific issues that may promote young people's interest in and uptake of science learning. (b) Partnerships with industry, researchers, and other professionals to bring into the classroom real-life projects, innovation, frontier research, and simulate authentic work in crucial areas. This enables more engaging and stimulating science learning while supporting the development of 21^{st} century competencies. (c) Conducting projects (via collaboration with local stakeholders) that address the challenges and needs of the local community and environment. Through this, schools deepen their links with their communities. (d) Enhancing family engagement, given the identified role of family influence on young people's career interests. (e) Addressing social equity issues, such as gender-related challenges, and embracing the idea of science for all (Mulero et al., 2022; Sotirou et al., 2017; Sotirou et al., 2021).

Open Schooling addresses various challenges in education, including science education. It aims to improve the quality of science education, spark students' interest in science, develop competencies for the modern workforce, strengthen community well-being, and foster social inclusivity. The M.Ed. program in Integrative STEM Education incorporates Open Schooling attributes, tailored to its specific goals. For instance, it embraces social inclusivity by considering the multicultural nature of Israeli society. This is particularly important as cultural and ethnic diversity introduces different perspectives, beliefs, traditions, and norms that shape individuals' worldview and behaviour. By acknowledging these aspects, the program aims to prepare educators to navigate the complexities of a diverse society effectively (Goldman and Alkaher, 2023).

3. The M.Ed. program approach from the lens of Open Schooling

The 'Integrative STEM Education' program aspires to develop teachers and professionals from various STEM backgrounds to lead change in formal and informal education settings. An assumption is that while the different STEM disciplines each have their own unique knowledge structure, principles, and methods, they share cross-disciplinary ideas, practices, and research methods, thus enabling them to apply relevant knowledge and transfer principles and methods from one discipline to another in problem-solving processes in the real world. The program emphasizes the development of three main categories of skills and competencies that today's school graduates need to succeed in their STEM studies and careers (EU, 2018; Tytler, 2020): learning skills (i.e., critical thinking and autonomous learning); literacy skills (i.e., information processing and technology); and social skills (i.e., collaboration and leadership). In view of the central role of sustainability issues in 21st century life, much of the learning in the program is anchored in this context. The program also raises social and ethical aspects interwoven in STEM fields, including the integration of women and minorities.

The curriculum addresses four main goals, developing students': (1) Knowledge and understanding of the STEM fields distinctly and interactively; (2) Pedagogical content knowledge, and technology PCK in teaching STEM with emphasis on project-based learning (PBL) as a leading method in long-term learning activities (Dagan et al., 2023); (3) Skills to lead and manage an interdisciplinary STEM approach in schools; and 4) Teachers' capacities to look at their work as a field for research. The program includes: (a) Mandatory courses (e.g., Creativity and Innovation in Development and Design Processes, Ethics and Values in STEM Education, Biomimicry); (b) Research seminars (e.g., Reforms & Changes in STEM Education); and (c) Electives (e.g., Energy Past, Present, and Future) (Dagan et al., 2019; Ragonis et al, 2017; 2019). The program structure and courses are presented in Figure 1. Pedagogies implemented in the courses that seek to serve as examples and inspiration for the students' to use in their own classes include: student-centered approach, active learning, long-term learning activities, room for choice in assignments, learning from complex case studies from academia, industry, and education actively involving the stakeholders in the learning process, creating a learning community of the students and faculty, student engagement in planning their own assessment, and co-teaching with faculty from different areas of expertise. These principles reflect several aspects of the OS approach (Sotirou et al. 2017) in terms of pedagogies, learning context, and personal growth.



* The courses described in the paper

Figure 1. Program structure and courses

4. Open schooling principles in the program courses

Open Schooling principles are central to the program and are expressed in all its courses. Following are representative examples of two courses in the program.

4.1 Analysis of interdisciplinary projects and research in academia and industry.

The course aims are: Exposure to authentic projects and research to understand the importance of integrating disciplines to find solutions; in-depth understanding of the skills that promote excellence in STEM; examining analogies among the various fields of knowledge; becoming acquainted with the work of researchers and engineers; deep understanding of research and problem solving processes and development methods employed in academia and industry; and development of the students' critical and creative thinking. To achieve these aims, the course activities gradually constructed students' comprehension of how interdisciplinary content facilitates solving real-world problems, and how skills enable them to achieve that. Core activities of the course: an introductory lecture by an expert in the field of education aimed at challenging the traditional structure of schools; study of the evolution of educational policies regarding STEM skills from a global and Israeli perspective; investigation of a community-oriented project of the students' choice with emphasis on the integration among the knowledge areas and skills; presentation of case studies from industry and research institutions by the teams; in-depth analysis of the presented case-studies employing criteria collaboratively built by the course's students and faculty; individual reflection to unpack their perceptions regarding knowledge areas, the roles of skills, and potential implementation in schools.

For example, a university research group presented an alternative energy project, showcasing the entire research cycle from multiple perspectives. Students worked in multidisciplinary teams, analysing the project through relevant knowledge areas, interdisciplinary approaches, and necessary skills. This example demonstrates OS attributes through teamwork, students' engagement in reverse engineering an authentic interdisciplinary case, and researchers' involvement in the learning process. The OS approach is evident in selecting real interdisciplinary cases and engaging students based on their disciplinary backgrounds. Furthermore, personal growth is fostered as students develop a deep understanding of sustainability-oriented issues and research complexities, providing a foundation for integrating them into their teaching practices.

4.2 Development and implementation of an integrative STEM educational project

In this advanced PBL course, the students apply diverse knowledge and experiences acquired in previous courses toward developing, as a team, an interdisciplinary PBL-based STEM learning unit, implementing it in their respective schools, and conducting an evaluation study of the process via action research (Seminar course). The aims of this course are to: (1) Develop a learning unit that reflects integration among STEM fields and employs PBL principles, (2) Implement the unit and assess it via the lens of PBL principles. PBL is the major guiding principle of this course and is expressed in the way the course is conducted (i.e., how the students learn), the pedagogy of the study unit developed by the students, and how the unit is implemented with the students' pupils in school. OS-related learning context is reflected, for example, in the selection of the driving-question, which is required to address a relevant challenge confronting the school community and work with relevant in-school and out-of-school stakeholders in the development and implementation of the learning unit. Figure 2 briefly visualizes one of the learning units with a focus on how it reflects the principles of PBL and OS around an integrative STEM learning unit.

Ethical gambling- is there such a thing?

Point of departure: Driving question suitable for learning probability

Driving questions	**STEM subjects**	**Learning activities**	**Collaboration**
How are gambling machines programmed in terms of players' luck? What is considered fair in gambling? Can fairness be calculated mathematically? How?	**Math** (statistics, probability) **Engineering** (Making) **Computer science** (programming) **Social science** (economic – ethical dilemma)	**Inquiry & debate** about gambling in Israel from social & legal aspects. **Inquiry** – how g. machines work in terms of probability of winning. **Program** fair gambling machine (based on pre-known probability) Build fair gambling machine in **maker lab**. **Prepare statistical report** based on wins/ loss on the machines. **Create & present poster** of the project in school event.	**In school:** Teachers from different subjects (technology, computer science, math). **Community:** Local industry that serves as a community-oriented learning center.

Figure 2. Principles of PBL and OS in the integrative STEM learning unit developed by the students

5. Preliminary findings

We explored the first cohort students' perceptions regarding the contribution of collaborating with professionals and learning around sustainability development (SD) issues to their learning and contributing to their work as teachers and educators.

The students identified SD issues as a fertile anchor for cultivating an interdisciplinary understanding of complex real-world issues, the skills and the emotional disposition that their students require in order to prepare them for the contemporary world. For example, "Dealing with sustainability is relevant to students all over the world. Students should engage in environmental problems that are authentic to their place and community…through this they experience the STEM principle of place-based learning and will become part of the solution" (T); "Social responsibility, ethical questions, and 21st century skills need to be expressed when dealing with sustainability issues, otherwise, it is hard to reach a solution or change the situation" (E). Learning from professional stakeholders around authentic projects enhanced this, as described by one of the students: "Encountering real-life projects deepened the understanding that to be ready for the future world, students need to learn in an integrative way, to establish broad knowledge in many areas, understand the connections among these areas, and know how to make new connections that will lead to new developments" (T).

The students' response to what they take from their studies into their work as teachers and educators highlighted several of the central attributes of OS for meaningful science education (Table 1). T's response reflects the role of Citizen Science, in which young people collaborate with scientists (and industry) toward preparing them as competent citizens (Wals et al., 2014). E's response underscores one of the central aims of OS – that schools become agents of community well-being. Y expressed how she experienced one of the main challenges confronting constructive education: reorienting her role as a teacher from that of a transmitter of information to that of a facilitator in the student's active learning process (Sterling, 2009).

Table 1. Students' perceptions about the contribution of collaborating with professionals and learning around sustainability development issues to their work as teachers and educators

T.: STEM teacher	E.: Technology teacher	Y.: Biology teacher
"**Apprenticeship**– I wish pupils could be part of projects in research and industry as assistants, in data collection or in other suitable roles, to gain firsthand experience from professionals … real world learning that makes learning significant and relevant … develop their self-capacity, work ethics, internal resilience, and rich vision of the future."	"Integrating people from the community into my teaching models to show the students that teachers don't know it all demonstrates the importance of teamwork, inquiry based on reliable sources, and **partnerships for the public good**."	"As a biology teacher it changed my way of looking at teaching, connecting between subjects, **teaching differently** – instead of transmitting content from the books teaching via inquiry tasks."

6. Summary

A challenge facing contemporary education is leading change to interdisciplinary STEM education that enables deep conceptual understanding, develops 21st century skills, is relevant to the pupils' lives, and motivates their interest. Interdisciplinary learning in STEM in schools still faces challenges, and much learning is still siloed according to school subjects (Tytler, 2020). OS is conducive to addressing these challenges (Mulero et al., 2022). The M.Ed. program 'Integrative STEM Education' is a 'Living-Lab', which reflects several aspects of OS, aspires to change the teachers' mindsets and build their competencies to function as agents-of-change who will lead the incorporation of integrative STEM education in their respective teaching environments.

This paper presented the program's central concepts in terms of how it incorporates aspects of OS in the overall program structure, courses, and teaching and focuses part of the learning around sustainability challenges. Preliminary findings with the first cohort of graduates of this program support the impact of this approach in preparing these teachers to function as change agents in their educational settings in terms of both enhancing integrative learning around STEM and linking this to the crucial role of sustainability education.

References

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA press.

European Union (2018). *Council recommendation on key competences for lifelong learning*. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018H0604(01)&from=EN

Dagan, O., Ragonis, N., Wagner, T., & Goldman, D. (2019). Integrative STEM education - A new M.Ed. program: Development, objectives, and challenges. *Proceedings of Pupils Attitudes Toward Technology - PATT 37: Developing a knowledge economy through technology and engineering education*, (pp. 125–132). Msida, Malta, 03-06, June 2019.

Dagan, O., Ragonis, N., & Goldman, D. (2023, In press). Insights from the implementation of the course 'Development of an interdisciplinary STEM project via PBL approach' in an 'Integrative STEM Education'. *M.Ed. program, PATT 40: The 40th International Pupils' Attitudes Towards Technology Research Conference*.

Goldman, D. & Alkaher, I. (2023). Outdoor environmental education: Grounding a tradition within environmental education. In J. Činčera, B. Johnson, D. Goldman, I. Alkaher, & M. Medek (Eds.), *Outdoor environmental education in the contemporary world - International explorations in outdoor and environmental education, Vol 12*, (pp. 11–32). Springer. https://doi.org/10.1007/978-3-031-29257-6_2

Hazelkorn, E., Ryan, C., Beernaert, Y., Constantinou, C.P., Deca, L., Grangeat, M., Karikorpi, M., Lazoudis, A., Pintó, R., & Welzel-Breuer, M. (2015). *Science education for responsible citizenship, Report to the European Commission of the expert group on science education*. European Commission Publications Office. doi:10.2777/12626

Mulero, L., Cunill, J., Grau, M. D., & Mancho, F. (2022). Studying forests in an open schooling project. *Journal of Technology and Science Education*, *12*(2), 362–378. doi.org/10.3926/jotse.1461

Philips, S., 2006, "Exploring the potential of open schooling, Connections, 11(1), pp. 8-10.

Ragonis, N., Dagan, O., Wagner, T., & Goldman, D. (2017). *REAL STEAM for developing the next generation problem solvers*. MASHAV Educational Training Center, May 2017 Booklet STEM.

Ragonis, N., Wagner, T., Goldman, D., & Dagan, O. (2019). Integrative STEM M.Ed. degree aligning with contemporary perspectives in academia and industry. *The 13th Conference of the European Science Education Research Association (ESERA)*, Bologna, Italy, 26-30 August 2019.

Sotiriou, S., Cherouvis, S., Zygouritsas, N., Giannakopoulou, A., Milopoulos, G., Mauer, M., et al. (2017). Open schooling roadmap: A guide for school leaders and innovative teachers. Ellinogermaniki Agogi.

Sotirou, M., Sotirous, S., & Bogner, F. X. (2021). Developing a self-reflection tool to assess schools' openness. *Frontiers in Education*, *6*, 714227. doi: 10.3389/feduc.2021.714227

Sterling, S. (2009). *Sustainable education – Re-visioning learning and change*. The Schumacher Society.

Tytler, R. (2020). STEM education for the Twenty-First Century. In J. Anderson & Y. Li (Eds.), *Integrated Approaches to STEM Education. Advances in STEM Education*, (pp. 21–43). Springer.

Wals, A. E. J., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science education and environmental education. *Science*, *344*, 583–584.

FLEBOCOLLECT: STEM education and citizen science project

A. Bermejo, A. Mora-Urda, M. López de Felipe, D. Bermúdez-Rochas, L. del Álamo, R. Gálvez

Universidad Autónoma de Madrid, Spain,

e-mail: angela.bermejo@estudiante.uam.es

Abstract

Flebocollect is a STEM and citizen science project to study leishmaniosis disease and the impact of ecosystem alteration on the emergence of diseases. The aim of this project is to analyse the impact of STEM activities for students and community members when being involved in school-community projects on environmental issues.

Keywords

citizen science, Leishmaniosis, Flebocollect, board game

1. Flebocollect project and the material topic

Flebocollect is a STEM and citizen science project to study leishmaniosis disease and the impact of ecosystem alteration on human health. It started in 2019, within the framework of the BRITEC (Bringing Research Into The Classroom) project, funded by the European Union in the Erasmus+ KA2 Program (2018-2021). Currently, "Flebocollect: Didactic strategy for the development of scientific competence through the study of emerging diseases with reference FCT-21-16782" is an ongoing project funded by the Spanish Foundation for Science and Technology - Ministry of Science and Innovation, to carry out activities to promote scientific, technological and innovation culture. The project includes carefully designed classroom tasks and materials that are proved to be "powerful tools for enhancing the quality of mathematics and science teaching, influencing the classroom culture and fostering students' learning", as this topic 2 line states. Before starting it, the spiral model of professional development has been used: analysis – implementation – reflection. Project investigators carried out several pilot tests with students of different levels of education, both primary and secondary. These allowed the modification and improvement of the activities and materials that make up the project. Likewise, these pilot tests were carried out in different scenarios, both in ordinary classrooms of educational centers and in the Museum of Natural Science in Madrid. Overall, this project aims to analyse the effectiveness of STEM activities and how materials can be useful for students and community members when being involved in school-community projects on environmental issues.

2. Flebocollect project: objectives, organization and materials

2.1 Objectives of the project:

Flebocollect scientific dissemination project is structured through a didactic sequence aimed at disseminating the consequences of the alteration of ecosystems in the emergence of diseases. Through this didactic sequence, designed by researchers in experimental science didactics and researchers with expertise in leishmaniosis, Flebocollect will bring science, technology, and research activity closer to students and the public through an experience in which they have to put into play the skills and knowledge of scientists. These didactic objectives are complemented by the scientific objectives of the project that focus on mapping the abundance and distribution of sand flies (insects' vectors that transmit leishmaniosis) in the Community of Madrid. Moreover, the focus has also been placed on the analysis of the instruments used, as well as on the possible failures derived from their implementation, to improve the methodologies and resources used. In addition, a report of each group-class participants will be provided to the teachers, with an exhaustive assessment of the degree of development of scientific competence and previous alternative ideas to know the deficiencies and strengths of the students and thus build a future didactic program that adjusts to the reality of the classroom.

2.2 Organization of the project:

Students in this line take all the activities included:

1-Board game: With this activity, raise awareness about the role played by the alteration of ecosystems in the appearance of diseases is introduced in the classroom. This game has been made from fragments of real scientific research on the leishmaniosis outbreak that emerged recently in the Community of Madrid (Spain). It includes a dashboard, cards, and reports with information obtained from scientific papers to guide the investigation. Thus, the student will be able to discover the origin of this outbreak and the particularities of its infective cycle (Bermejo and Gálvez, 2022).

2-Do it-yourself traps (DIY traps): This activity is about the construction of their own DIY light traps (Do It Yourself) made with recycled materials, for the capture of phlebotomine sand flies, insects that transmits leishmaniosis (Gálvez et al., 2022). Subsequently, traps will be installed in the vicinity of the educational centers, homes, or surrounding parks. Participants are provided with the necessary materials and procedures to construct their traps. Afterward, they have to install the traps and identify captured species. Data on captured sand flies reported to researchers through online application will be used to map out their presence in the area and hence the risk of leishmaniosis.

3-Infographic contest: Students carry out the preparation and digital design of infographics that raise awareness about the leishmaniasis outbreak and provide advice and recommendations on how to avoid the infection and how to reduce the emergence of new leishmaniosis outbreaks.

2.3 Preliminary results of activity 1:

By the time this congress is held, we would be able to bring some results: the level of scientific competence developed, the degree of knowledge acquired, the motivation and willingness of the students. Moreover, improvements to be made will be measured. Before and after the board game activity, a test will record the perceptions and ideas of the students. The pre-test presents questions to find out the previous ideas of the students about concepts of health and disease. On the other hand, the post-test has questions to measure the degree of development of scientific competence, questions in which students must analyze and synthesize the information given in graphs, tables, or fragments of scientific research.

Acknowledgments

This study was funded by the Spanish Foundation for Science and Technology - Ministry of Science and Innovation, to carry out activities in the field of the promotion of scientific, technological and innovation culture (Id. BDNS nº 592032), through the project "Flebocollect: Didactic strategy for the development of scientific competence through the study of emerging diseases" with reference FCT-21-16782. In addition, AB has received an economical contribution, "Ayudas Inicio a la Investigación" conceded by the Universidad Autónoma de Madrid.

References

Bermejo A. & R. Gálvez_R. (2022). *OUTBREAK: The strange case of leishmaniasis outbreak in the Madrid region*. In Experiencias y estrategias de innovación educativa en ciencia, tecnología, ingeniería y matemáticas (III); ((pp. 213–220). Editorial SM).

Gálvez_R., López de Felipe, M., & Yebes, F. (2022). Citizen science set in motion: DIY light traps for phlebotomine sand flies. *Preventive Veterinary Medicine*, *200*, 105589.

Fostering learning on sustainability: Plastic soup with escape boxes

Alice Veldkamp, Sanne Korte

Freudenthal Institute, Utrecht University, the Netherlands

e-mail: a.veldkamp@uu.nl

Abstract

Commercial escape rooms have inspired teachers to adapt the popular entertainment activity for education, especially in STEM education. This global bottom-up phenomenon in education is implemented in several ways. Students use their knowledge and skills either to solve problems and "escape" the room or finish an escape game in time.

This article explores why escape games are suitable for education on the topics of sustainability and climate change. Furthermore, it introduces a framework grounded in theories on game-based learning, which focusses on the three main challenges for the use of educational escape rooms. This framework was used to develop escape games such as on the topic of plastic soup. Subsequently, a study explored which game elements contributed to the appreciation and learning with escape games.

Keywords

escape rooms, escape games, escape boxes, game-based learning, collaborative learning, climate change education, sustainability education

1. The rise of escape rooms in education

Globally, escape rooms have been finding their way into education, especially in STEM education. Escape rooms are live-action team-based games in which players encounter challenges to complete a quest in a limited amount of time. The quests in the first rooms were 'escapes', nowadays the quest varies, for example to solve a murder mystery or break into a vault (Nicolson, 2015). STEM teachers implement escape rooms to foster learning in authentic contexts such as laboratories or outside world contexts which are out of reach, potentially dangerous or abstract for learners, like plastic soup. STEM escape rooms create feelings of mastery, ownership, and mutual dependence, resulting in high student engagement, regardless of age or gender (Lathwesen & Belova, 2021; Veldkamp, 2022).

2. Ways in which escape games can be used in education

Usually, escape games are implemented in two ways; teams of students use their knowledge and skills either to solve the escape game or develop one themselves. In a previous project, we combined these two ways. Based on design-based research, students developed in three design cycles reusable escape boxes, with various game content for secondary education on plastic soup, zoonosis and carbon dioxide emission. The escape box has changeable fronts. The fronts offer various tools, such as a laptop screen, a magnet board, and hatches with locks. Puzzles placed on each side of the fronts put players face to face with each other, see Figure 1. These games are researched and used in secondary education (Veldkamp, 2022).

Figure 1. An escape box with the game Plastic Soup during a playtest by knowledge experts

3. An escape game design

Within an escape game, all problems or activities are called puzzles. As escape games are inherently team-based games, the puzzles tend to ensure that every member of a team is active and can contribute (Nicholson, 2015). The puzzles, which can be categorized as: 1) cognitive puzzles that make use of the players' thinking skills and logic, 2) physical puzzles that require the manipulation of artifacts to overcome a challenge, and 3) a meta-puzzle, the last puzzle in the game in which the final solution is derived from the results from the previous puzzles. Cognitive puzzles seem to predominate in escape rooms (Nicholson, 2015). To solve the puzzles, players require skills such as searching, observation, correlation, memorization, (logic) reasoning, math, reading and pattern recognition (Wiemker et al., 2015). After the gameplay, the gamemaster debriefs the players on the process and what they have achieved (Nicholson, 2015). Educational escape rooms can be considered a form of serious gaming. Its design is more complex than that of commercial or recreational escape rooms as the game design needs to combine educational design with game design (Lameras et al., 2017; Whitton, 2018).

4. The main challenges for the use of educational escape games and game elements that addresses them

There are three main challenges for the use of educational escape games 1) the students transition from the real world to the game world, 2) the alignment of game design aspects and educational aspects, and 3) the transfer from attained experiences and knowledge back into the real world. In a study, Veldkamp (2022) explored how educational game design elements related to each of the challenges contribute to the appreciation of and learning with an escape game, see Figure 2.

The first challenge is the participation of students into an educational escape game. In secondary education, the students' transit from the science class into the game world, is not as voluntary as in a recreational game. To persuade students, the game element immersion is important. Immersion is the process where someone is lured into a story or problem (Douglas & Hargadon, 2001), gets engaged, solves challenges, and finishes the game (Hamari et al., 2016). Immersion correlates with improved learning outcomes in science game-based learning (Cheng et al., 2015).

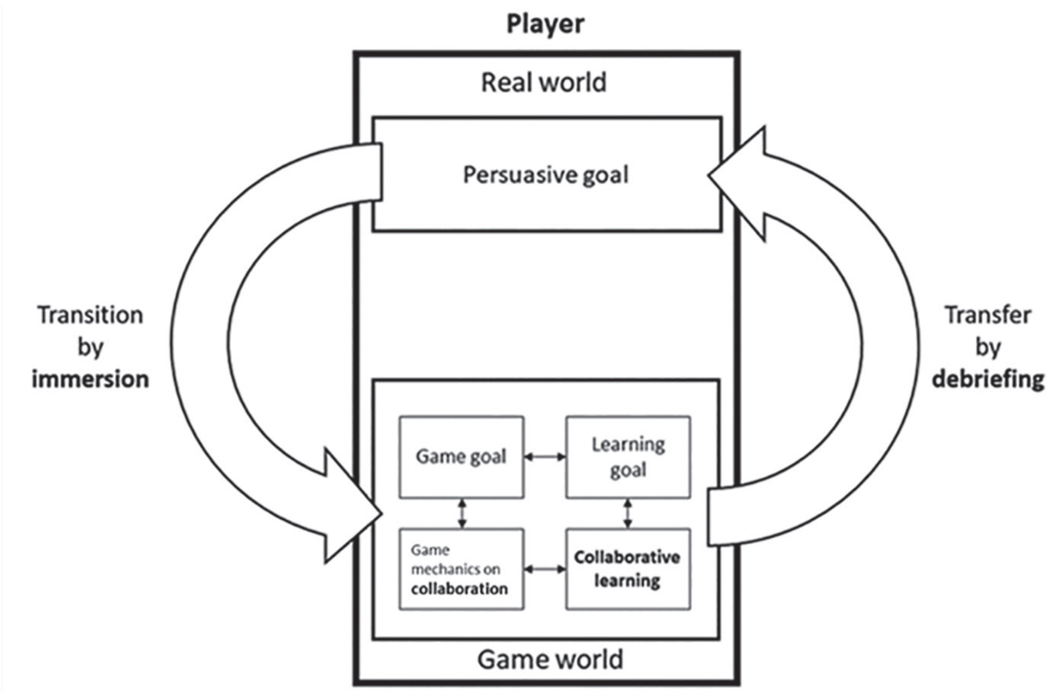


Figure 2. An educational game design framework for escape rooms, focussing on the three main challenges 1) the participants' transition from the real world to the game world, 2) the alignment of game design aspects and educational aspects, and 3) the transfer from attained experiences and knowledge back into the real world. In bold the game elements addressing the challenges are highlighted. (Veldkamp, 2022)

The second challenge in an educational game is the alignment of game design aspects and educational aspects (Van der Linden et al., 2019). Van der Linden's framework addresses the different alignments needed in a successful educational game. It needs to be ensured that the game goal can only be reached when the desired learning goal is reached. Additionally, a learning goal can only be achieved when supported with an adequate pedagogical approach, and the game goal by adequate game mechanics. Moreover, during iterations of the design process the focus should be on aligning the pedagogical approach with the game mechanics, as it appears the most essential and difficult step. As a pedagogical approach, STEM escape rooms aim at collaborative learning. In collaborative learning environments learners are engaged; working together to formulate questions, discuss ideas, explore solutions, complete tasks and reflect on them (Srinivas, 2011; Kozlov & Groβe, 2016). Learners interact to reach a shared goal (Dillenbourg, 1999). In escape rooms collaborative learning is fostered with supportive game mechanics fostering collaboration, such as time restriction, adequate puzzle organisations and team sizes (Veldkamp, 2022).

The third challenge is the transfer from attained experiences and knowledge back into the real world. Debriefing is needed (Sanchez & Plumattez, 2018; Watson et al., 2011). Watson et al. (2011) see teachers as agents bridging the game world and the real world. The debriefing after an educational game is a complex process as the experience and knowledge need to be decontextualised and institutionalised for future contexts. Therefore, teachers need to discuss the game experience and puzzles, link puzzles to learning goals and content, and discuss the learning for broader application (Veldkamp, 2022; Sanchez & Plumattez, 2018).

5. Evaluation of the framework and the escape boxes

Study method. Based on the framework a mixed-method study was carried out to explore how educational game design elements related to each of the challenges, contribute to the appreciation of and learning with an escape game, see Figure 2. The activity was played with a total of 126 pre-A-level students, aged 16-20 yrs. To determine whether learning actually took place, a pre-test/post-test was deployed. To study how the game design elements influence learning in an EG, various data sources were used: experience questionnaires, interviews with students and teachers, and classroom observations (see Table 1).

Table 1. The various data sources and numbers of participants

Data source	**Number**	**Female, male, other**
Students - pre-test/post-test	126	68, 57, 1
Students - experience questionnaire	126	68, 57, 1
Students - interviews	14	
Teachers - interviews	5	
Classroom - observations	6	

Data collection. For the statements for the experience questionnaire a 5-point Likert scale was used, ranging from 'totally disagree' to 'totally agree'. Six teams were observed closely; every student was observed once a minute, using a predefined coding scheme. For the semi-structured interviews, a non-random sampling strategy was used.

Data analysis. To determine the reliability of the tests and experience questionnaire, the calculated Cronbach's alpha was respectively 0.78, 0.72 and 0.81. A Wilcoxon signed-rank test was used to determine whether the students gained knowledge. Data were analysed using Spearman's rank correlation test. On the classroom observations, descriptive statistics were used. All interviews were transcribed verbatim and analysed independently by two researchers following Boeije (2010).

Results and conclusions. Students answered positively on appreciation question for the game (4.5/5 Likert scale). Additional analysis (Mann-Whitney U testing) showed no gender preferences.

The means of the pre-test/post-test scores showed that learning took place (Wilcoxon's Z= -9,8, $p < 0.0001$). The appreciation of the activity correlates positively with the appreciation of each of the game design elements. This indicates that the appreciation does not depend on one of the design elements, but all contribute, see Table 2.

Table 2. The Spearman's correlation coefficients on relations between the students' appreciation of the activity (Q1), willingness for this type of activity in the future (Q2), their experiences on immersion, collaboration, debriefing and their knowledge gain. Note: * Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed)

Future	0.650**				
Immersion	0.457**	0.459**			
Collaboration	0.424**	0.506**	0.348**		
Debriefing	0.480**	0.402**	0.487**	0.337**	
Knowledge gain	0.203*	0.108	0.180*	0.088	0.108
	Appreciation	**Future**	**Immersion**	**Collaboration**	**Debriefing**

In relation to each of the studied design elements, we here only present the main conclusions, for more results, discussion, and conclusions, see Veldkamp, 2022. Although students' collaboration was successfully fostered and 76% of the time spent on the content knowledge, it scarcely led to collaborative learning during gameplay, due to lack of discussion and reflection needed for deeper understanding. Therefore, the debriefing seems vital. Students appreciated the debriefing, some students added in interviews that it is important that teachers add more to the debriefing than just a recap of the puzzles' content. Teachers regarded the debriefing as crucial for learning with an escape game.

Based on the results, most accountable for the knowledge gain during gameplay is immersion, scaffolded by the roles and boxes, resulting in a constant focus on tasks. It might be possible that immersion is a threshold element of the learning process, fostering mostly individual learning during gameplay, but limited. More immersion in the game leads only to higher game scores, but not to higher science learning outcomes (Cheng et al., 2015).

6. Advantages & challenges in the use of escape rooms for education on climate change and sustainability

Advantages

Monroe and colleagues found in their systematic review on identifying effective climate change strategies two themes, (1) focusing on personally relevant and meaningful information and (2) using active and engaging teaching methods. Escape games have the possibility to address both. Research showed that escape rooms are immersive, interactive learning environments and students are behaviourally, cognitively, and emotionally engaged. Furthermore, no gender differences are found in appreciation or learning outcomes, regardless of the age of the student. Science teachers use escape games to bring topics which are abstract, dangerous, or unreachable for students into the classroom (Veldkamp, 2022). Climate change and other sustainability topics are usually abstract for students.

Educational escape games for sustainability and climate change is a pioneering field. From 2018 onwards, studies and/or articles on educational escape rooms can be found (see examples in the list below this article). As discussed in section 1, escape games have characteristic game elements, such as time restriction and teamwork. Both these game elements can support the message (and goal) of the game. The time restriction supports a sense of urgency in relation to the topic and can be logically embedded into the narrative. As an escape game is a team-based game, which requires teamwork and different skills and knowledge, it can support the environmental message ‘together we need to solve it, or prevent this type of problems’, and this can be embedded in the story line. Part of the playfulness of an escape game is that it creates purposely uncertainty, because at first sight it is not clear what to do or how to handle a puzzle. To handle uncertainty is a skill which is needed in addressing the global problems of climate change and sustainability. In a debriefing, the teacher can address these feelings of uncertainty and students’ coping mechanisms.

Challenges

It is claimed that educational escape rooms can support necessary skills needed for climate change and sustainability, such as critical thinking and problem solving (Ouariachi & Elving, 2020). However, the puzzles are linked on forehand in a strict organisation. In addition, the solution of the puzzles which is checked by a digital or physical lock is also strict, usually a number code or word. Therefore, students need to find programmed answers. Until now, puzzles in an escape game are not yet open-ended problems as sustainability or climate change problems are. However, the games are suitable to create awareness and inform on such topics. More research is needed for fostering necessary skills on the topic such as problem solving, critical thinking, system thinking, and future thinking.

To wrap up, escape games, such as escape rooms or boxes are immersive, interactive learning environments for abstract problems as climate change and sustainability. The learning environment can create a temporarily (future) world with a clear shared goal and message, supported by escape room game elements such as time restriction, collaboration and a narrative in which players have an active role. Finally, the discussed framework (Figure 2) could help educators in creating these immersive games which not only engage learners but also achieve learning gains.

Articles on climate change and sustainability escape rooms

Chang, H. Y. H. (2019). *Escaping the gap: Escape rooms as an environmental education tool*. University of California.

Gündüz, Ş. (2018). Preventing blue ocean from turning into red ocean: A case study of a room escape game. *Journal of Human Sciences*, *15*(1), 1–7.

Mello, G., Reuter, J., Dias, M. F., & Amorim, M. (2021). Promoting Environmental Education with Escape Room Activities: Critical Factors for Implementation. In *European Conference on Games Based Learning* (pp. 535–XV). Academic Conferences International Limited.

Ouariachi, T., & Elving, J. L. (2020). Escape rooms as tools for climate change education: an exploration of initiatives. *Environmental Education Research*, *26* (8), 1193–1206.

Reuter, J., Mello, G., Dias, M. F., & Amorim, M. (2022). Developing environmental awareness competencies through a sensorial escape room. In *ICERI2022 Proceedings* (pp. 6357–6365).

References

Boeije, H. (2010). *Analysis in qualitative research*. Sage Publishing.

Cheng, M. T., She, H. C., & Annetta, L. A. (2015). Game immersion experience: its hierarchical structure and impact on game-based science learning. Journal of Computer Assisted Learning, *31*(3), 232–253.

Dillenbourg P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and computational approaches* (pp. 1–19). Elsevier

Douglas, J. Y. & Hargadon, A. (2001). The pleasures of immersion and engagement: schemas, scripts and the fifth business. *Digital Creativity*, *12*(3), 153–166.

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior*, *54*, 170–179.

Kozlov, M. D. & Große, C. S. (2016). Online collaborative learning in dyads: Effects of knowledge distribution and awareness. *Computers in Human Behavior*, *59*, 389–401.

Lameras, P., Arnab, S., Dunwell, I., Stewart, C., Clarke, S., & Petridis, P. (2017). Essential features of serious games design in higher education: Linking learning attributes to game mechanics. *British Journal of Educational Technology*, *48*(4), 972–994.

Lathwesen, C. & Belova, N. (2021). Escape rooms in STEM teaching and Learning—Prospective field or declining trend? A literature review. *Education Sciences*, *11*(6), 308.

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., & Chaves, W. A. (2019). Identifying effective climate change education strategies: A systematic review of the research. *Environmental Education Research*, *25*(6), 791–812.

Nicholson, S. (2015). *Peeking behind the locked door: A survey of escape room facilities*. Available at https://scottnicholson.com/pubs/erfacwhite.pdf (Accessed: 2 December 2022).

Sanchez E. & Plumettaz-Sieber, M. (2019). Teaching and learning with escape games from debriefing to institutionalization of knowledge. In M. Gentile, M. Allegra, & H. Söbke (Eds.), *Games and Learning Alliance. GALA 2018. Lecture Notes in Computer Science*, 11385, 242–253. Springer. https://doi.org/10.1007/978-3-030-11548-7_23

Srinivas, H. (2011). *What is collaborative learning*? The Global Development Research Center. Retrieved September 16, 2021, from http://www.gdrc.org/kmgmt/c-learn/index.html.

Van der Linden, A., Van Joolingen, W. R., & Meulenbroeks, R. F. G. (2019). Designing an intrinsically integrated educational game on Newtonian mechanics. In M. Gentile, M. Allegra, & H. Söbke (Eds.), *Games and Learning Alliance, Lecture notes in computer science* vol. 11385 (pp. 123–133). Springer. https://doi.org/10.1007/978-3-030-11548-7

Veldkamp, A. (2022). *No Escape! The rise of escape rooms in secondary science education*, Ph.D. Thesis. Utrecht University. Available at: https://dspace.library.uu.nl/handle/1874/416526 (Accessed: 2 December 2022).

Watson, W. R., Mong, C. J., & Harris, C. A. (2011). A case study in-class use of a video game for teaching high school history. *Computers & Education*, *56*, 466–474.

Whitton, N. (2018). Playful learning: Tools, techniques, and tactics. *Research in Learning Technology*, *26*.

Wiemker, M., Elumir, E., & Clare, A. (2015). Escape room games: “Can you transform an unpleasant situation into a pleasant one?”. In J. Haag, J, Weißenböck, M.W. Gruber, M. Christian, & F. Freisleben-Teutscher (Eds.), *Game based learning*. Fachhochschule st Pölten GmbH. pp. 55–68.

Girl empowerment in STEM education by means of summer camps

Josette Farrugi[1], Maria Evagorou[2], Dita Kreuz[3], Vincent Jonker[4],

[1]University of Malta, Malta, 2 University of Nicosia, Cyprus, 3 ICSE, University of Education Freiburg, Germany, [4]Utrecht University, the Netherlands

Abstract

Around half of Europe's population is female, yet only 15% work in tech sectors and even less, 2,4% in ICT related fields. Only around 20% of the females are entrepreneurs. The untapped source of female technology, innovation and entrepreneurial potential leaves Europe with a huge and growing gender and skills gap in these sectors. Education certainly is the most important lever to enable and encourage girls to pursue stutdies and careers linked to STEM, particularly information and communication technology (ICT), and entrepreneurship.

The project 'Girl empowerment in STEM Education' (GEM) focussed on increasing girls' interest in STEM and ICT subjects, studies and careers, by organising summer camps for girls in 10 European Countries and by establishing a network of European institutions with the same objectives.

Higher education institutions from 10 European countries organized summer camps for girls, piloting various learning activities, which specifically supported the development of a diverse range of STEM related and personal skills. Skills that enable girls to contribute to Europe's digital innovation processes.

Why STEM for girls summer camps

The GEM project (with 10 European countries involved) used an out of classroom context to support female students towards STEM. The decision to focus on out of school context is supported by previous studies based on which such a context has more possibilities to enhance young students' interest in STEM (Heeg, Smith & Avraamidou, 2022; Wieselmann, Roehrig & Kim, 2020) as opposed to a formal setting because a formal setting (i.e., school) might limit the authenticity of the experience (Braund & Reiss, 2006). The activities developed as part of the summer schools afford the ability to blur the boundaries between the STEM disciplines in a way that provides authentic integration. Additionally, the summer school setting allowed us to design activities that are longer in duration, provide authentic experiences through visits and field trips, and make it possible to work with scientists from multiple STEM disciplines because of the flexibility of the schedule. Previous studies report that summer schools and after class STEM activities should include hands-on nature of activities, collaboration, and opportunities to fail without the stress of being evaluated in a formal setting (Moore et al., 2014). The evaluation of previous summer schools and afterclass activities highlight that they are successful in increasing students motivation and STEM career aspirations (Kitchen, Sonner & Sadler, 2018), they empower students (Habig, Gupta, Levine & Adams, 2020) and can improve students' knowledge and interest in learning (Chen, Tomsovic & Aydeniz, 2014; Pitri, Evagorou & Stylianou, in print).

Pedagogical starting points for summer camps

In the context of this GEM collaboration the different European partners agreed on some pedagogical starting points:

- *Inquiry-based learning*

All activities will be based on collaborative activities, where girls have freedom to choose, to hypothesize, to collect, etc. And, as stated above, avoiding activities that resemble classical old-school STEM practices.

- *Context*

The contexts used in the summer camps were choosen from a wide range of socio-scientific issues, like energy transition, sustainability, waste problem, etc.

- *Culture*

When you only bring girls together another environment is created than a normal classroom situation. In all summer camps extra attention was given to a safe learning environment and a feeling of belonging

- *Role models*

In all summer camps female role models (from the workplace, from education) were central to the activities and workshops, in order to have this important input and enviroment for all girls.

- *Entrepreneurship*

This is strongly connected to the first issue mentioned: inquiry-based learning. It is putting the girls in their strength, putting extra effort into a growth mindset that entrepreneurs need.

Three examples of summer camps: Cyprus, Malta and the Netherlands

Cyprus: Observations, comments and reflections from the first implementation of the STEM summerschool were used by the local research group in Cyprus to prepare the new version that was implemented in June 2022. The main objectives of the new materials were to: engage young students with different STEM disciplines; make students understand STEM stereotypes, bring students in contact with female STEM professionals as role models; help students appreciate different aspects of STEM professions, engage students with skills linked to STEM (i.e. creativity, programing, inquiry-based learning, problem solving), engage students in problem solving and entrepreneurial activities.

Malta: In september 2022 about 60 girls joined for a Girls4STEM Week, and they worked in small groups of 6 to 7 students at a time. They were accompanied by a young female mentor. Activities like: Electromagnetics in medical diagnosis and treatment; Science in the investigation and preservation of Malta's national cultural heritage; NASA's Moon Survival Challenge, and of course some Coding activities.

The Netherlands: To get a good and meaningful learning environment we decided to have the three 'Autumn Girl Days' associated with 'bigger ideas'

- Trees Monday: measuring and calculating trees, practical 'exciting surfaces' and drawing a pythagorean tree;
- The Eye Tuesday: eye-tracking, medical physical research on eyes and building and using a camera obscura; and
- The Design Wednesday: mathematical folds, pseudo-coding and heights

Each day there was a meeting between the 20 participating girls and a so-called Girl of the Day talking about her scientific research and a speaker combining a workshop with a super interesting presentation. On the last day, as a group activity, the physics topics around forces, gravity and altitude were combined with a climbing workshop.

Examples of learning activities used in the summer camps

In the GEM Consortium we collect the learning activities that were used throughout the summer camps, in order to get an online collection that can be used in different situations (new summer camps, extra school activities, etc.), see Figure 2.

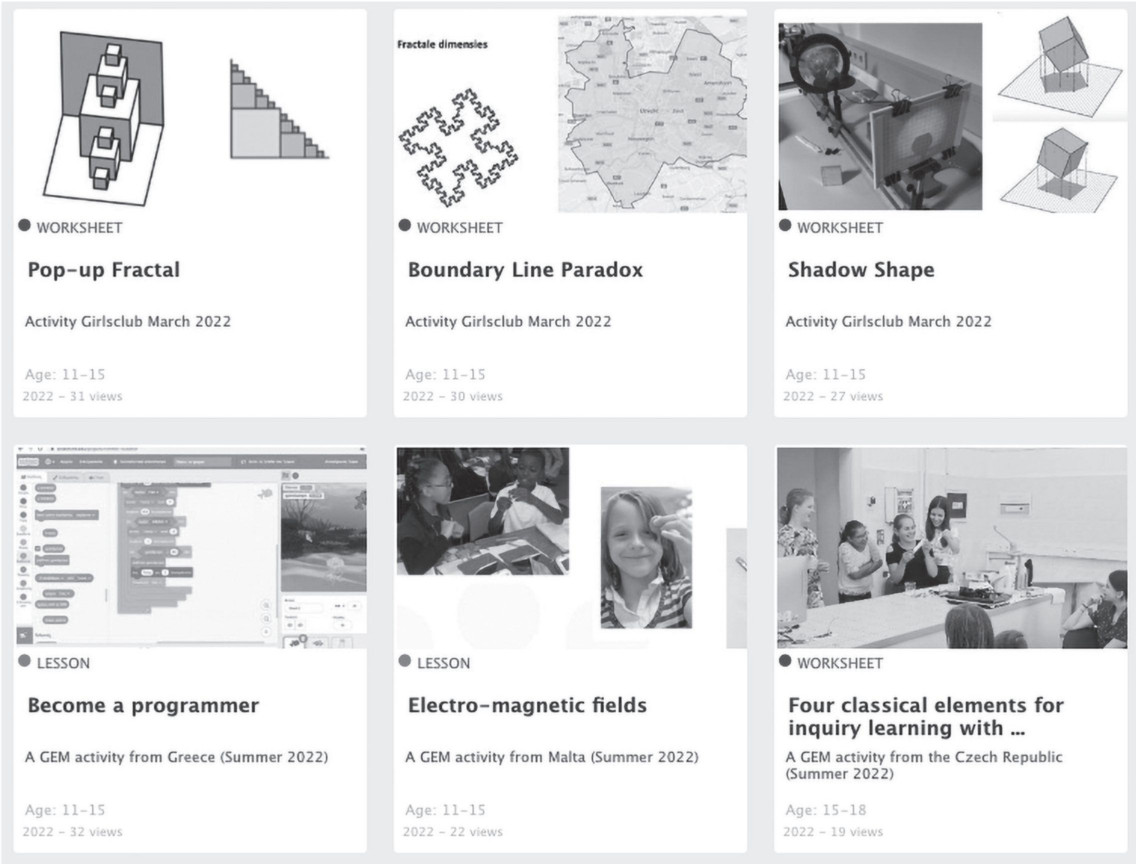


Figure 2 - Online repository of learning activities - https://www.fi.uu.nl/publicaties/subsets/girls4stem_en/

In all learning activities we collect the central idea, the way the activity was used in the camp, the materials used, the experience. We take an example from Cyprus: How colors can be used to improve the wellbeing of scientists (Working towards prototypes (ideas), supported by the so called design thinking process).

This collection of activities can be used for free, and can be found at the ICSE and GEM website.

Results from the evaluation of the summer camps

Data were collected across all summercamps (both in 2020 and in 2022), a final report on the evaluation results will follow in early 2023 (and will be included in the EtE IV workshop). A questionnaire was used to ask girls about their interest in STEM before and after the summer school (pre- and post), and based on these findings we can already state that students show an increase in their interest in learning about STEM, with the most important change in their views linked to the fact that after engaging with the curriculum most of the students report that now they understand how STEM can help them in their future careers and everyday life. Furthermore, students were asked to provide their feedback for the learning activities. The students commented very positively on the fact that they worked in groups most of the time, with one of them reporting that “My favorite activity was working on the product that we had to prototype and I enjoyed it because we worked as a group and had fun at the same time”. Working on prototypes and presenting (half)products was reported by all students as a positive aspect of the curriculum.

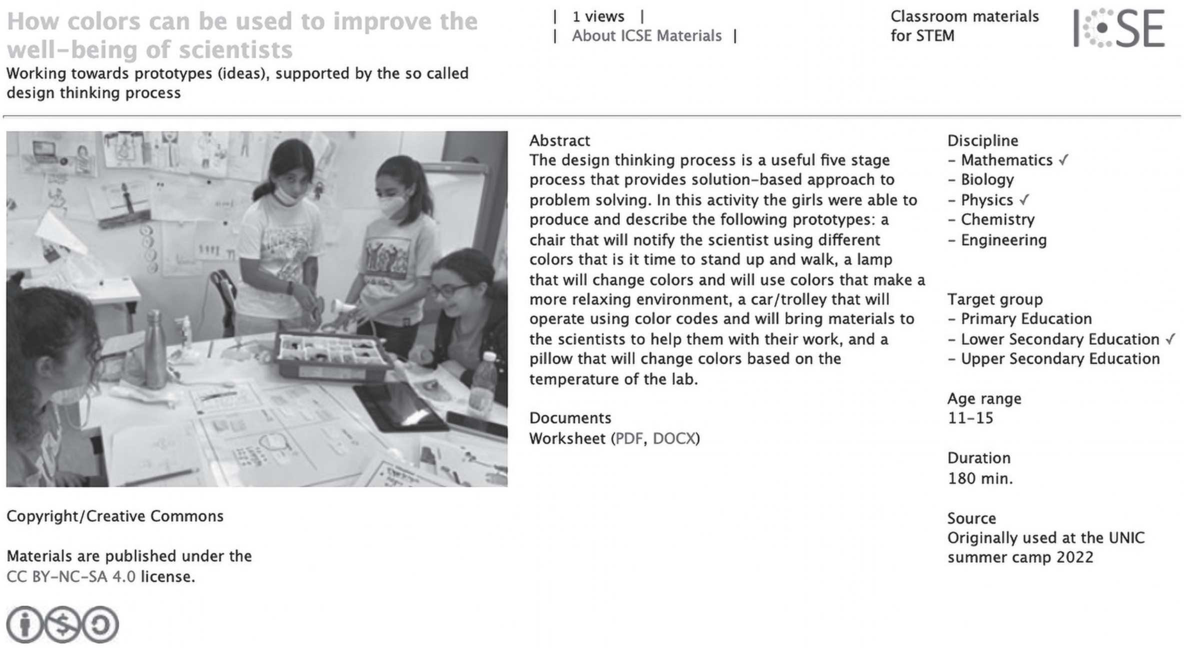


Figure 3 - Example of a learning activity https://www.fisme.science.uu.nl/toepassingen/29141/

Acknowledgements

This research was made possible by a EU Erasmus+ Grant under the name Empower Girls to Embrace their Digital and Entrepreneurial Potential. We like to thank all partners from the GEM project, from Germany, Czech Republic, Spain, Malta, Sweden, Cyprus, The Netherlands, Slovakia, Lithuania and Greece.

References

Braund, M., & Reiss, M. (2006). Towards a more authentic science curriculum: The contribution of out-of-school learning. *International Journal of Science Education*, *28*, 1373–1388. http://dx.doi.org/10.1080/09500690500498419

Chen, C., Tomsovic, K., & Aydeniz, M. (2014). Filling the pipeline: Power system and energy curricula for middle and high school students through summer programs. *IEEE Transactions on Power Systems*, *29*(4), 1874–1879, doi: 10.1109/TPWRS.2013.2293752.

Habig, B., Gupta, P., Levine, B., & Adams, J. (2020). An informal science education program’s impact on stem major and stem career outcomes. *Research in Science Education*, *50*, 1051–1074. https://doi.org/10.1007/s11165-018-9722-y

Heeg, D., Smith, T., & Avraamidou, L. (2022). Children’s experiences and self-identification with science in the context of an out-of-school STEM Program. *EURASIA Journal of Mathematics, Science and Technology Education*, *18*(4).

Kitchen, J.A., Sonnert, G., & Sadler, P.M. (2018). The impact of college- and university-run high school summer programs on students' end of high school STEM career aspirations. *Science Education*; *102*, 529– 547. https://doi.org/10.1002/sce.21332

Luo, T., So, W. W. M., Wan, Z. H., & Li, W. C. (2021). STEM stereotypes predict students' STEM career interest via self-efficacy and outcome expectations. *International Journal of STEM Education*, *8*(1), 1–13. doi:10.1186/s40594-021-00295-y

Moore, T. J., Stohlmann, M. S., Wang, H.-H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K–12 STEM education. In Ş. Purzer, J. Strobel, & M. E. Cardella (Eds.), *Engineering in Pre-College Settings: Synthesizing Research, Policy, and Practices* (pp. 35–60). Purdue University Press. https://doi.org/10.2307/j.ctt6wq7bh.7

Pitri, E., Evagorou, M., Stylianou, A. (in print). Reflections on the design of a STEAM curricula for 12-14 year old girls

Robinson, A., Simonetti, J. H., Richardson, K., & Wawro, M. (2021). Positive attitudinal shifts and a narrowing gender gap: Do expertlike attitudes correlate to higher learning gains for women in the physics classroom? *Physical Review Physics Education Research*, *17*(1), 010101. doi:10.1103/PhysRevPhysEducRes.17.010101

Steinke, J., Applegate, B., Penny, J. R., & Merlino, S. (2021). Effects of Diverse STEM role model videos in promoting adolescents' identification. *International Journal of Science and Mathematics Education*, 1–22. doi:10.1007/s10763-021-10168-z

Wieselmann, J.R., Roehrig, G.H., & Kim, J.N. (2020). Who succeeds in STEM? Elementary girls' attitudes and beliefs about self and STEM. *School Science and Mathematics*, *120*, 297– 308. https://doi.org/10.1111/ssm.12407

Hands-on commodity science

Susanne Gruber

Association for Research in Commodity Science Obersdorf / Vocational Business Schools BFI Vienna, Austria

e-mail: Susanne.gruber@aon.at

Abstract

Commodity science is an interdisciplinary field that examines the Supply Chain and the environmental impacts throughout the production chain, encompassing resource knowledge and the globalization of commodity markets. In laboratory lessons, students develop scientific skills and gain practical knowledge of product testing, enabling them to make informed decisions in the areas of trade, production, and consumption.

Keywords

commodity science, Warenlehre, hands-on experience, supply chain, laboratory lessons

Introduction

Commodity science endeavors to develop strategies for sustainable management and optimization of commodity resources, while addressing challenges such as disruptions in the supply chain and environmental impacts. It encompasses the study of the production, distribution, consumption, and trading of primary goods, including agricultural products, minerals, and energy resources. This field integrates knowledge from economics, agriculture, engineering, and environmental science to comprehend the behavior and dynamics of commodity markets. In recent years, the field has gained significant prominence due to the escalating demand for natural resources and the expanding globalization of commodity markets.

1. Teaching commodity science

In recent years, there has been a growing demand for sustainability education, particular aimed at young individuals who should possess a better understanding of products and the ability to evaluate their environmental impact.

In Austria, instruction in commodity science and technology has been provided in vocational business schools since the first “Handelsakademie” was founded in Vienna in 1857, which amounts to over 156 years of such education.

At all levels of education, it is crucial to impart fundamental knowledge about commodities. Students need to comprehend goods in their natural state and acquire skills such as describing commodities, conducting tests, and understanding the sociological and ecological consequences of their usage.

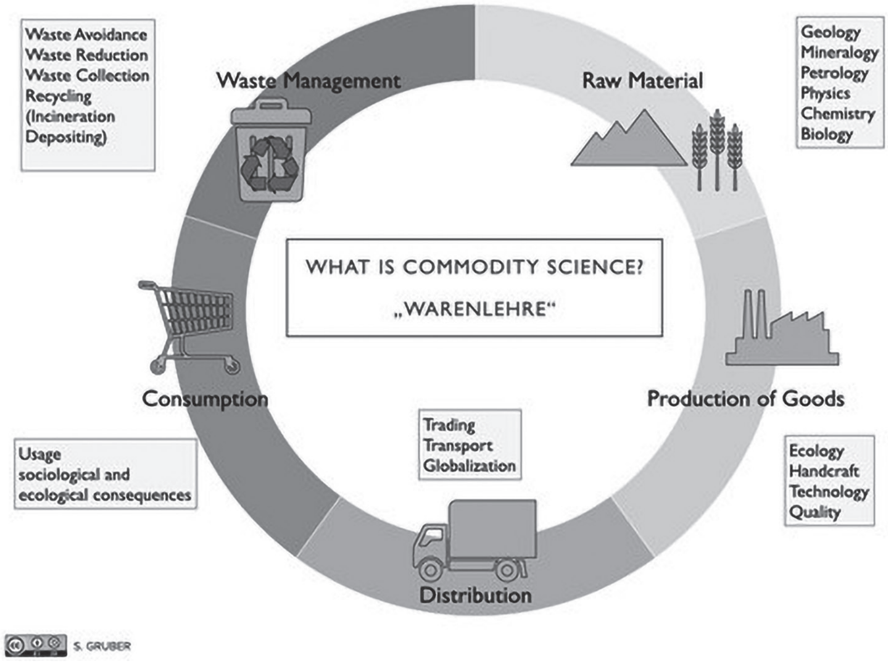


Figure 1: What is Commodity Science? – Warenlehre

The current standard teaching time allocated to commodity education in higher vocational schools, which amounts to 2 to 3 hours per week per year, appears insufficient given the extensive teaching material. It is hoped that supplementary courses or university programs will offer opportunities to acquire in-depth knowledge of products. Similar to other fields of education, it will be the responsibility of teachers to create engaging lessons. Experimentation is crucial for research-based learning, and product testing enables learners to interact with materials in a playful or research-oriented manner, catering to different skill levels. Such practices help train students to become critical consumers and entrepreneurs.

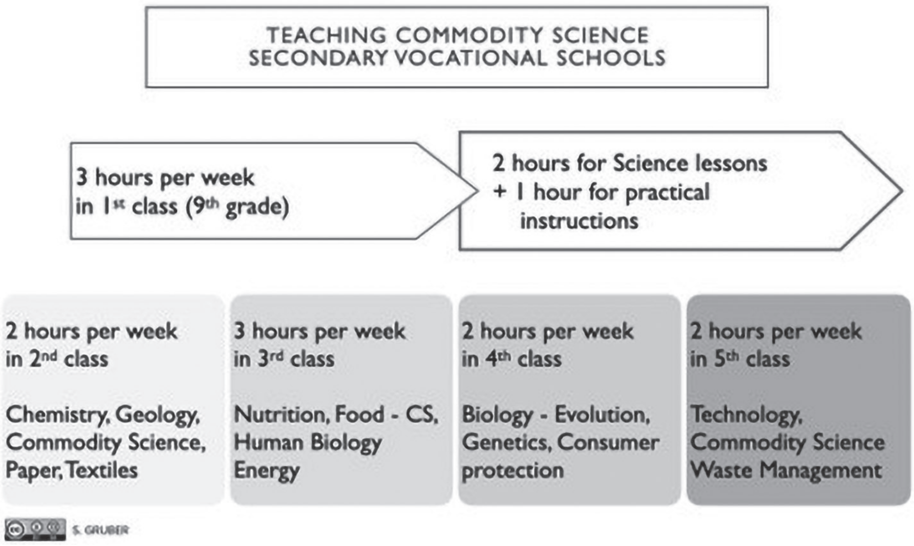


Figure 2: Teaching Commodity Science

During the laboratory lessons in Commodity Science, students gain hands-on experience with a variety of methods for testing goods. Examples of these lessons include:

1. Rapid tests for assessing the vitamin content of fruits and vegetables: Students learn how to perform quick tests to determine the vitamin levels in different types of produce. This allows them to understand the nutritional value of these commodities.
2. Examination of mineral properties and mineral identification: Students explore the characteristics and properties of minerals. They learn how to identify different minerals based on their physical and chemical properties, enhancing their understanding of mineral resources and their applications.
3. Investigation of metal properties: Students study the properties of metals, such as conductivity, malleability, and strength. They learn how to perform tests to assess these properties, which are crucial for understanding the uses and applications of various metals in different industries.
4. Determination of density for different types of wood: Students learn how to measure and calculate the density of different wood samples. This knowledge is important for industries that rely on wood materials, such as construction, furniture, and packaging.
5. Planning and execution of taste tests: Students learn the process of designing and conducting taste tests to evaluate the sensory qualities of food products. This helps them understand consumer preferences and the role of sensory evaluation in the marketing and sales of commodities.
6. Verification of the antibiotic effect of spices: Students explore the potential antimicrobial properties of spices. They conduct experiments to assess the effectiveness of spices in inhibiting the growth of microorganisms, highlighting the importance of food safety and preservation.

Through these laboratory lessons, students not only develop scientific skills but also gain practical knowledge of product testing, enabling them to make informed decisions in the areas of trade, production, and consumption.

2. Training of teachers

Until 2005, the University of Vienna and the Vienna University of Economics and Business taught the teaching profession “Biology and Commodity Science”. In addition to the biological, chemical and physical basics in the first semesters, this interdisciplinary course includes the entire Theory of goods, Commodity Science and Technology with inorganic and organic aspects in the second part of the course.

Until 2005, the University of Vienna and the Vienna University of Economics and Business offered a teaching program called “Biology and Commodity Science.” This interdisciplinary course covered the fundamentals of biology, chemistry, and physics in the early semesters, while the second part focused on the entire theory of goods, commodity science, and technology, encompassing both inorganic and organic aspects.

However, since 2006, students have been required to choose another subject to combine with commodity science. As a result, there is currently a lack of comprehensive knowledge, particularly in the areas of sustainability and the interconnected aspects of commodity science.

TRAINING OF TEACHERS IN COMMODITY SCIENCE

< 2005	▸ University of Vienna	Principles in Natural sciences	Geology, Mineralogy, Petrology Physics, Chemistry, Biology
	▸ Vienna University of Economics and Business	Principles in Production Processes	Technology, Commodity Science, Sustainability, Waste Management

2005 <	▸ University of Vienna	Biology or Chemistry or Physics	Geology, Mineralogy, Petrology Physics, Chemistry, Biology
	▸ There is no training facility	~~Principles in Production Processes~~	~~Technology, Commodity Science, Sustainability~~

Figure 3: Training of teachers

To address this gap, it is necessary to introduce a new curriculum at universities that enables future teachers to acquire a broad understanding of commodity theory and sustainability. The training for natural science teachers should not only encompass courses in biology, chemistry, physics, product information, and technology but also include instruction on effectively utilizing digital media. I propose the implementation of an interdisciplinary course that establishes close connections between the subjects from the beginning, embracing the concepts of CS 1.0 to 4.0. This approach will facilitate a holistic understanding of commodity science and its integration with contemporary advancements in technology and digital media.

Recently propagated Commodity Science 2.0 includes a modern view to the scientific field, to the development of new norms and a scientific projection of research into the future. (Cormode_G., 2008, Aghaei_S. 2012, MOOC 2016)

- Commodity Science 1.0 represents the foundational knowledge base of the field, encompassing traditional descriptions of goods and quality.

This requires teachers in the natural sciences, such as biology, chemistry, and physics, to possess fundamental knowledge in these areas.

- Commodity Science 2.0 (Zalewski_R 2014) represents an advancement in the understanding of commodities, organized within a framework that encompasses the utilization and description of the entire lifecycle of goods. Consumers benefit from new processes and technologies at the point of sale, including high quality, safety, and sustainability. In this domain, teachers should possess fundamental knowledge of production processes, including their environmental impact.
- Commodity Science 3.0 involves further developments, including automation, computer technology, and the use of machines to facilitate production and everyday life. Future teachers should be trained in handling digital software and using digital media in teaching.
- Commodity Science 4.0 will encompass the development of artificial intelligence, digitization, and robotics. Teachers should acquire the ability to teach coding and robotics fundamentals and assess the applications of artificial intelligence.

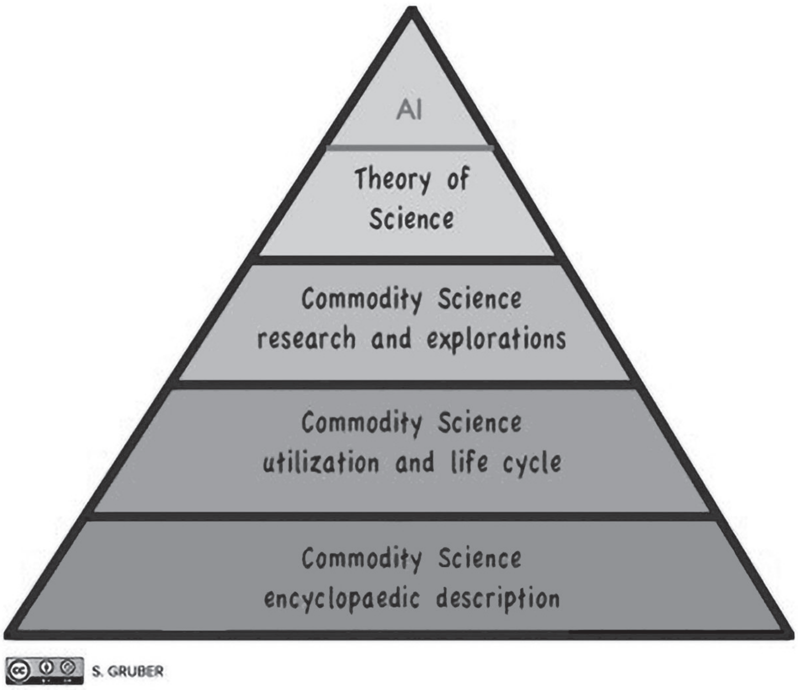


Figure 4: Structure of Commodity Science

These progressions in Commodity Science represent the evolving nature of the field, with an increasing focus on technology, digital literacy, and sustainability. Educating future teachers in these areas will enable them to effectively navigate and impart knowledge within a rapidly changing landscape.

3. Interdisciplinary experimental teaching

Teachers should strive to incorporate practical assignments and bring hands-on experiences to the classroom, particularly in secondary vocational schools. The advent of distance learning has opened up new opportunities to compensate for the limited time available for practical work in science classes.

Experiments can be adapted to be conducted at home, allowing for the growth of microorganisms or the extraction of DNA from fruits. With simple materials and devices that are commonly found in households, experiments can be better understood. Practical lessons at home and in experimental sessions at school should include the following components:

- Clear instructions provided by the teacher through video, conferences, or written materials.
- Precise safety instructions to ensure the well-being of the students, especially when working with water, heat, or open flames near their computers.
- Utilization of readily available materials and household items, such as candles, knives, spoons, glasses, vinegar, cooking oil, salt, sugar, flour, rice, milk, spirits, and food colouring.
- Comprehensive documentation of the experiments, including written reports and accompanying photographs.
- Debriefing sessions conducted via video conferences and written feedback provided by the teachers.

It is crucial to emphasize that adult supervision cannot be assumed during these experiments. Providing precise safety instructions becomes even more critical when students are working independently at home.

During distance learning, the success of students has shown an increase of 20 to 30% compared to previous years. This success can be measured by the number of completed assignments and the total number of points achieved. Students are required to engage more intensively with the experiments due to the necessary preparation involved.

By implementing practical assignments and adapting them for distance learning, teachers can enhance student engagement and promote a deeper understanding of scientific concepts.

References

Aghaei, S., Nematbakhsh, et. al. (2012). Evolution of the World Wide Web: From Web 1.0 to Web 4.0. *International Journal of Web & Semantic Technology IJWesT*, 3.1, 1–10. http://airccse.org/journal/ijwest/papers/3112ijwest01.pdf, accessed 30th August 2016.

Cormode, G. & Krishnamurthy B. (2008). Key differences between Web 1.0 and Web 2.0. *First Monday*, *13*(6), http://firstmonday.org/ojs/index.php/fm/article/view/2125/1972, accessed 21st October 2014.

MOOC Online course, Mooin Schule 4.0: https://mooin.oncampus.de/course/view.php?id=47&chapter=3&selected_week=16, accessed 22d August 2016.

Zalewski, R. (2014). *Commodity science 2.0 and problems of sustainable growth for improvement of life quality*. Plenary session Commission of Commodity Science of the Polish Academy of Sciences, 19th IGWT Symposium, 15 – 19 September 2014, Cracow, Poland.

Healthy beverages factory. Integrated STEAM project for primary school

Juan Fraile, María Antonia López-Luengo

Universidad de Valladolid. Sciences Education, Social Sciences Education and Mathematic Education Department, Segovia, Spain

e-mail: juan.fraile@estudiantes.uva.es

Abstract

The proposal implemented Project-Based Learning (PBL) and the STEAM approach in a Primary School, aiming to enhance integrated learning and include students with special educational needs. It focused on sustainability, sustainable production, and pollution, with the goal of transforming the environment and creating sustainable products. Students developed skills in math, science, arts, and social science, while creating a fictional sustainable factory for producing healthy drinks. The project resulted in improved performance, increased motivation, and the development of various skills. It serves as an example for STEM education, emphasizing real-world application and pedagogical reflection.

Key words

project-based learning (PBL), STEAM Education, primary school, sustainability, environmental education, health education

1. What is “Healthy beverages factory”

The learning project that is presented was developed in a Primary School center. The didactic proposal is based on Project Based Learning (PBL) and the STEAM approach. It was designed to enhance student’s learning from an integrated perspective. This mixed methodology allows the teacher to develop an open teaching-learning process that integrates all the students (Kim, 2021). It was implemented in a context where it was relevant to integrate some students with special educational needs.

PBL encourages commitment and motivation that students need to solve real world tasks. The process leads to a final product that allows them to develop skills and knowledge for real life (Cheng & Yong, 2019). PBL also fosters cooperative skills through collaborative project work, enabling learners to effectively work together, communicate and achieve shared goals (Johnson & Johnson, 2018). It is also known that the STEAM approach helps students to acquire either skill for solving real world tasks and creativity (Perignat & Katz, 2019).

Initially, this educational approach focused on integrating Science, Technology, Engineering and Mathematics into real-life learning situations. However, the incorporation of art allows for a new way of perceiving and understanding the world, enhancing the skills acquiered in the other STEM fields (Wynn & Harris, 2013). The convergence of both methodologies, PBL and the STEM approach, benefits the creation of a solid and integrated curriculum, which can substantially increase the engagement of PK-12 students for learning (Bequette & Bequette, 2012). From this perspective, this project sets an interesting material for Primary School teachers.

This proposal proceeds from the general topic of Sustainability, in particular sustainable production, and pollution, to reflect on how we can transform our environment and create sustainable products. The project tries to bring the students' context to reflect about sustainable production, renewable energies, healthy consumption, and the necessity to preserve the natural environment. The curricular integration has allowed students to develop skills from different disciplines as math, science, arts, and social science, learning by thinking and solving real life problems (Brown, 2017).

2. Description of the experience

2.1 Context

The project took place during April and May in 2022, with a small group of 12 students (ages between eleven and twelve) from a public school based in Segovia (Spain). In the group there were four students with special educational needs, and the project sets a new approach to promote an inclusive education. It lasted three weeks during which ten sessions of variable duration were held. During the project the students worked in four heterogeneous groups.

2.2 STEAM contents

In this integrated STEAM project, students will explore and create a comprehensive understanding of sustainable production and healthy consumerism, working across various subject areas.

Firstly, in the Science component, students will delve into the concept of energy and its relevance in productive sectors, examining different energy forms and their applications. Additionally, they will investigate the importance of healthy nutrition and its impact on overall well-being. The Technological domain involves studying the production process of a specific drink, using real-life tools to produce a healthy beverage. Moving on to Engineering, the emphasis will be on project planning and management. Collaboratively, students will design and execute the production project efficiently, considering resource allocation, and ensuring a successful and sustainable outcome.

Next, in the Art component, students will work on graphic and audio-visual productions to enhance the presentation and marketing of the beverage product. They will also create visually appealing designs for packaging and labels. Finally, Mathematics plays a fundamental role in the project. By incorporating statistical analysis and measurement, students will interpret data related to energy consumption, nutritional values and production processes. In addition, surveys will be conducted at the school to gather preferences regarding beverages.

2.3 The development of "Healthy beverages factory"

The general topic of the project was the creation of a sustainable factory that produces healthy drinks. While the factory was fictional, the students came to elaborate a real drink in the classroom. During the process the students had a digital diary where they registered the progress and learnings they were doing. The project had four phases with different steps.

The first phase consisted of the explanation of the project. After it was exposed, it started the second phase, which consisted in the research of information. The first step was to carry out surveys in the school, to know flavors and kinds of beverages that would be interesting to produce. The second step was to investigate the production sectors, and to deduce how each one will contribute to the production of a drink. It was said, for instance, that it will require some fruits and milk, and energy for the factory.

The next step was to investigate energy, looking for a renewable type that can be used to produce the beverages in the factory. Then, in a different session, they must propose solutions to decrease the impact that the factory could have on the environment. Then, the next step consisted of the elaboration of the beverage. They first had to investigate substances, materials, and blends, and to design the first recipe for the drink. After that, they properly created the beverage in the class and tasted it until they found the flavour they really wanted (Figure 1). To finish this phase, students had to find an NGO that works for sustainability, and to think about how they would collaborate with them.

Furthermore, a supplementary session was held where students created labels using recycled paper. This complements the significance of promoting sustainable development and provides further guidance towards recycling. The students shredded used paper with water and reassembled it to form new paper on which they wrote food labels and relevant information about the product (Figure 2). The last two phases consisted in the organization of the materials to create a poster and an advertisement to announce the beverage and their work. Each group creates their own video, their beverage, and their poster, that were held in the classroom.

To conclude, there was an evaluation process after all the materials were presented to the class. The digital diary, group productions and final presentations were assessed, considering the group´s teamwork and its contribution to the final product. To ensure a comprehensive evaluation, rubrics were used, and students actively participated in co-assessing the final presentations.

Figure 1. Beverage production

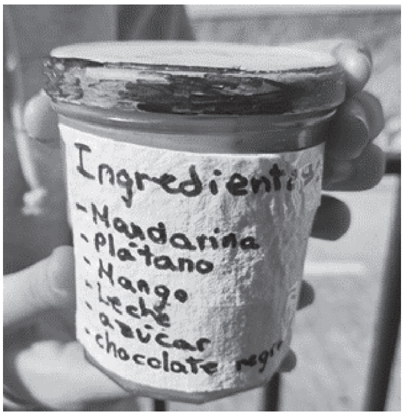


Figure 2. Package beverage with label

3. Final reflections

The implementation of this project has benefited global learning. All the class improved their performance on the final test. Motivation towards learning increased in almost all students. Some positive ideas about health and sustainability grew up in the class, while students develop relevant skills in math, science, digital art, creativity, and entrepreneurship. Students demonstrated a conscious effort towards promoting healthier options and sustainable practises, reflecting their awareness and commitment to these important values.

Students reflect in their personal evaluation that they prefer to learn by practice instead of writing. Specifically, they found that the activities related with energy were excessively theoretical. On the other hand, the surveys were considered very positive, and the results opened new lines of activities in the school.

The groups worked properly in general terms. However, there were occasions when a person had to work more than their mates. While some groups worked in a balanced way, others needed the teacher´s order to work to succeed in the practices. This shows the importance of designing balanced groups with students that can cooperate using different skills.

On the other hand, the project presented can serve as an example that other teachers can adopt in the context of STEM education. It provides a framework for incorporating STEM concepts and skills in a real-world, project-based approach that engages students and promotes their learning. The project also focuses on the pedagogy employed and includes a reflection about it. The reflection highlights the successes and challenges of the project, as well as the lessons learned by the teacher as an educator. This reflection can help other teachers to adapt and improve upon the project in their own teaching context.

As a future prospect, involving students in the design process of the proposal is essential, enabling them to shape the direction of their work, whether it is related to beverage production or the implementation of sustainable energy practices. Therefore, it is crucial to propose a flexible learning process in which competences emerge through didactic situations. In addition, the project´s duration can be extended as long as the different STEAM competences are significantly explored. It is also important for students to be aware of how their learning will be assessed, and constant feedback and feedforward should be provided during the sessions.

References

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the Stem conversation. *Art Education*, *65*(2), 40–47.

Brown, M. A. (2017). Integrating STEM education through project-based learning. *Journal of STEM Education: Innovations and Research*, *18*(3), 14–20.

Chen, C. H., & Yang, Y. C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review*, *26*, 71–81.

Johnson, D. W., & Johnson, R. T. (2018). Cooperative learning: The foundation for active learning. In S. M. Brito (Ed.), *Active learning-Beyond the future*, (pp. 59–71). IntechOpen.

Kim, M., 2021, "STEAM and project-based learning for interdisciplinary education: A systematic literature review", Journal of Educational Technology & Society, 24(1), 238–253.

Perignat, E., & Katz, J. (2019). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity*, *31*, 31–43.

Wynn, T., & Harris, J. (2013). Toward a STEM+ arts curriculum: Creating the teacher team. *Art Education*, *65*(5), 42–47.

How does the CriThiSE PD-model support teachers in implementing critical thinking in sustainability education at upper primary school?

Ragnhild Lyngved Staberg[1], Eldri Scheie[2], Niklas Gericke[3]

[1] *Department of Teacher Education, Norwegian University of Science and Technology (NTNU), Trondheim, Norway*

[2] *Norwegian Centre for Science Education, University of Oslo, Oslo, Norway*

[3] *Department of Environmental and Life Sciences, Karlstad University, Karlstad, Sweden*

e-mail: ragnhild.l.staberg@ntnu.no

Abstract

This study is conducted within the project CriThiSE (Critical Thinking in Sustainability Education), which is a large-scale three-year longitudinal initiative that aims at scaling-up the implementation of Critical Thinking (CT) in the context of sustainability education in primary school. In cooperation with teachers, we develop their CT instructions and investigate if and how these instructions are enacted in their classrooms, and further investigate the influence on students' development as critical thinkers. In this paper, we focus on the structural and context dependent aspects of the professional developmet project based on the experiences of using a specifically developed professional-development model (PD-model) in the five different intervention schools. By using a mixed method approach including interviews and questionnaires with the teachers from the ongoing project we discuss their experiences of the PD-model and its implementation at the different local schools. Most of the teachers perceived that they got a new and developed understanding of how to teach critical thinking in the context of sustainability education. However, we also discuss the experienced obstacles relating to structural issues such as school leadership and the working organization.

Key words

critical thinking, longitudinal study, primary school, professional development-model, sustainability education

1. Introduction

This presentation relates to Topic 3 (Structural dimension) and addresses the question: "What structures are needed for implementing and sustaining open schooling initiatives, such as school-community projects, on environmental issues?" Our study is conducted within the context of the project CriThiSE (Critical Thinking in Sustainability Education), which is a large-scale initiative that aims at scaling-up the implementation of Critical Thinking (CT) in the context of Education for Sustainable Development (ESD) in primary school. The goal is to develop students' ability to relate critically and at the same time democratically to different perspectives on sustainability issues.

As teacher educators, we have designed a research-based Professional Development (PD) program for in-service teachers. Our aim is twofold: Firstly, to equip primary teachers in science and other subjects with knowledge about ESD and CT, as well as competencies in teaching these topics. Secondly, by working with in-service teachers across regions and countries, we aim at spreading the classroom implementation at national levels. In our presentation we will explain our PD-model, as well as the in-service teachers' perceptions on the implementation of this model. The PD-model is meant to be used by teacher educators, hence the relevance to the overall conference theme (Educating the Educators) and to Topic 3. Our presentation will be addressed from a target group-specific perspective, i.e., in-service teachers' experiences. We intend to use the oral presentation format.

2. Theoretical background and rationale

In the last decades, much research has been done in relation to continuing professional development (CPD) and related quality criteria have been developed. To be effective, CPD should be collaborative and extended over time, include time for practice, coaching, and follow-up, be grounded in students' curriculum, and aligned with local policies, be job-embedded and connected to several elements of instruction (Caena, 2011; Desimone, 2009; Lipowsky & Rzejak, 2012; Putnam & Borko; 2000). Research indicates that communicative and cooperative activities represent the core factors fostering sustainable impact of CPD programs (Lerman & Zehetmeier, 2008). Lerman and Zehetmeier (2008) also state that, in particular, providing rich opportunities for collaborative reflection and discussion (e.g., of teachers' practice, students' work, or other artifacts) presents a core feature of effective change processes. There is also growing evidence that collaboration among teachers is a key ingredient for effective CPD (e.g., Schleicher, 2016). However, we need more insights on the interplay of material, features of the CPD course and the background conditions (Lipowsky & Rzejak, 2015). In this study we therefore aim to develop and implement a PD program in different contexts and analyse the outcomes thereof.

CT has been proposed to be one of four main competences to promote within sustainability education (Church & Skelton, 2011), and suggested to be an underlying basic competence in ESD to develop students into action competent individuals in complex environmental issues (Wiek et al., 2016). Others express CT explicitly as a key competence, as going deeper into sustainability challenges will require a critical approach (UNESCO, 2017; Scheie et al., 2022) CT is also suggested to be a necessary competence in combination with the other sustainability competences (Scheie et al., 2022). However, there is a gap between policy and practice, and it has not been shown how CT can be integrated into sustainability education. In the project Critical Thinking in Sustainability Education (CriThiSE) we are addressing this issue by working with primary teachers in an educational design project where the aim is to develop teaching of CT within sustainability education and investigate the outcomes thereof. As part of the project, we therefore develop a PD program on CT within sustainability education.

3. Context: Critical Thinking in Sustainability Education (CriThiSE)

This study was carried out within the framework of the project CriThiSE (Critical Thinking in Sustainability Education). CriThiSE is a cooperation between Norwegian University of Science and Technology (NTNU), Karlstad University, Sweden (The SMEER Centre), Norwegian Centre for Science Education, National Centre for Writing Education and Research, The Nordic Institute for Studies in Innovation, Research and Education (NIFU), and five schools: one in Sweden and four in Norway. The project is financed by The Research Council of Norway, and is coordinated by Department of Teacher Education, NTNU.

The primary objective of the project is to develop teaching of critical thinking (CT) and investigate the outcomes thereof in primary education. CT is emphasized as a central twenty-first century skill - central in education, work life and civil society. Today's schools therefore need to educate coming generations in a way that encourage them to reflect critically on their own and others' decisions. This is a crucial issue where elementary school education should contribute to coming decades in order to facilitate continued democratic advance of society, as also recognized in the new Norwegian curriculum and governing documents. Sustainability challenges are complex, where values and knowledge form the basis for the decisions made. To validate the important choices that must be made in a pluralistic and democratic society, competence in CT is crucial (Davies & Barnett, 2015).

In CriThiSE we are conducting a longitudinal study of what it means to think critically in school. We develop and evaluate teaching of CT within different contexts of ESD and within different subjects. In cooperation with teachers, we develop their CT instructions and investigate if and how these instructions are enacted in their classrooms, and further investigate the influence on students' development as critical thinkers.

The project started 01.01.2020 and includes a 3-year intervention in upper primary school (grades 5-7) at five schools. Before the intervention started, we collected pre-surveys from teachers and students (60 control schools and 5 intervention schools) and conducted teacher and student interviews (intervention schools). In the spring of 2023, we will carry out post-tests at both control schools and intervention schools to see if the intervention has had an effect on teachers and students. Control schools take part in quantitative data collection (pre and post), while intervention schools take part in quantitative and qualitative data collection (pre, post and halfway). The presentation will include preliminary results of teachers' experiences.

4. The CriThiSE PD-model

The overall purpose of the PD program is to develop teaching methods for ESD and CT in upper primary school and how they can be an integrated part of everyday teaching. The purpose is also to develop abilities in the students to take part in fruitful conversations about complex issues without simple answers that include a diversity of values and viewpoints, with a sound, critical stance.

The PD design was based on local PD studies (Haug & Mork, 2021; Scheie & Stromholt, 2019), as well as design principles from Caena (2011) and Desimone (2009). The work structure of our PD-model is presented in figure 1. We run three workshops á 2 hours per semester, in total 18 meetings over a period of three school years. During each workshop teachers exchange experiences, and teacher educators present new theory, didactics and model a new classroom activity. Between meetings, teachers practice collaborative work, try-outs and student involvement. During the last school year, the teachers will plan and carry out a larger project at their own school which is based on an authentic dilemma.

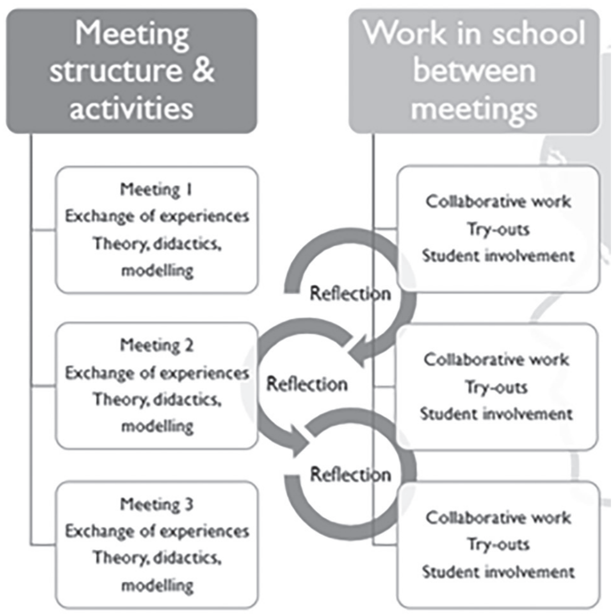


Figure 1. CriThiSE PD-model

5. Methodology

The data collection for this presentation used a mixed method approach including a teacher questionnaire from five intervention schools, and focus group interviews with a sample of teachers. In total, 48 Norwegian and Swedish primary school teachers answered the questionnaire. The teachers had teaching experience ranging from 0 to 40 years, averaging to 14 years. The results were analysed using descriptive statistics. Teachers from five different schools teaching 5th to 7th Grade were selected via opportunity sampling to take part in focus group semi-structured interviews. During the interview they were asked to elaborate on "can you think about how your understanding of CT has changed during the intervention and how this affects your teaching?" Interviews were subject to thematic analysis (Robson & McCartan, 2016).

6. Preliminary findings and discussion

Based on the preliminary analysis of the interview data we see that teachers from intervention schools have a more nuanced picture of CT than before, e.g., as illustrated by this statement: "Before, I thought that paying attention to sources, being critical of sources, was critical thinking. Now, because of the intervention, I am much more aware of the importance of CT and see it in relation to my students and teaching in several ways". They are more conscious, see more possibilities on how to include CT in their teaching and see the importance of giving students the right tools, e.g., "I feel that I have become more aware of it in my teaching, how to use it. I think this has come about because we have talked more about it and tested various activities with the students. I see more now how important it is that students learn to think critically and get some tools to practice it". Teachers see the importance of CT for students as future citizens; "CT and dilemmas in sustainability in teaching create commitment and motivation, both for me as a teacher and my students. Students reflect and think about questions that we teachers don't know the answer to either, participate in discussing dilemmas that concern them about their own lives. This will prepare students for society and help them to use their own voice."

These qualitative results are supported by quantitative data from teacher surveys. In the survey we asked teachers about their teaching practice "before" the CriThiSE intervention and 2 years into the intervention. Their answers changed over these two years. For example, on the statement "I think that the teaching should have conversations where different perceptions are presented and discussed" the proportion who responded "to a very large extent" changed from 17% before to 48% after the intervention. Likewise replying to the statement "I should encourage students to have their own opinions on the issues we are working on" their answer to a "very large extent" changed from 28% to 52%. Furthermore, the answer to "students should examine critical the content of texts they read" changed from 22 % to 52 % in the category "to a very large extent". Considering the statement "teaching should be linked to current events", their answer in the category "to a very large extent" changed from 20% to 48%.

There are several success stories from teachers participating in the intervention, but both we, as a research group, and the teachers have faced several obstacles. Professional development in school depends on the principal's participation and commitment. In one of the schools, the principal was replaced twice. This had a major problematic impact on both the meetings with the teachers and the general communication with the school. At one of the other schools, the collaboration between the teachers did not work in one of the grades. This led to few conversations, elaboration and little use of dilemmas and CT in their teaching. In general, the teacher has little time for planning and preparing in depth for their own teaching, while the intervention use, in comparison, a lot of time discussion small steps in teaching about dilemmas and CT. The teachers were supposed to both discuss with their colleagues and plan for their own teaching about ideas received at the intervention. It took quite a long time to incorporate this practice with the teachers so that we could discuss experiences from their own teaching at the next meeting. It was a complicating factor that the teachers should work in interdisciplinary teams. Additionaly, the teacher groups were supposed to work together between the meetings. This also meant that the principal had to set up planning time for teacher groups between the meetings, but this often did not happen. Our obstacles are in line with Gericke and Torbjörnsson (2022), who found that scepticism, ambiguous management and local contexts hampered the intended change. Still, several teachers saw the benefit from working at school with tasks from the intervention and even though the intervention is still ongoing, teachers indicate that they benefit from it, and especially the try-outs and student involvements: "I see the benefit of these meetings more when I have carried out teaching with the student related to what we had last time. I become more motivated and also get to reflect on my own experiences from the classroom. It increases my competence as a teacher".

Acknowledgements

CriThiSE (Critical Thinking in Sustainability Education) received funding from the Research Council of Norway, FINNUT, under grant agreement number 302774.

References

Beilin, R., & Bender, H. (2010). The getting of interdisciplinarity: The everyday practice of environmental curriculum design. In *Interdisciplinary higher education: Perspectives and practicalities* (pp. 181–193). Emerald Group Publishing Limited.

Caena, F. (2011). Literature review Quality in Teachers' continuing professional development. *Education and Training 2020*.

Church, W., & Skelton, L. (2010). Sustainability education in K-12 classrooms. *Journal of Sustainability Education*, *1*, 1–13.

Davies, M. & Barnett, R. (2015). Introduction. In M. Davies & R. Barnett (Eds.), *The Palgrave handbook of critical thinking in higher education* (pp. 1–25). Springer.

Desimone, L.M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, 38(3), 181–199.

Gericke, N., & Torbjörnsson, T. (2022). Supporting local school reform toward education for sustainable development: The need for creating and continuously negotiating a shared vision and building trust. *The Journal of Environmental Education*, doi:10.1080/00958964.2022.2102565

Haug, B. S., & Mork, S. (2021). Taking 21st century skills from vision to classroom: What teachers highlight as supportive professional development in the light of new demands from educational reforms. *Teaching and Teacher Education*, 100, Art. 103286.

Lai, E. R. (2011). *Critical thinking: A literature review. Research report*. Pearson.

Lerman S., & Zehetmeier, S. (2008). Face-to-face communities and networks of practicing mathematics teachers. In K. Krainer & T. Wood (Eds.), *The international handbook of mathematics teacher education. Volume 3, Participants in mathematics teacher education. Individuals, teams, communities and networks* (pp. 133–153). Sense Publishers.

Lipowsky, F. & Rzejak, D. (2012). Lehrerinnen und Lehrer als Lerner – Wann gelingt der Rollentausch? Merkmale und Wirkungen wirksamer Lehrerfortbildungen. *Schulpädagogik heute*, 3(5), 1–17.

Lipowsky, F. & Rzejak, D. (2015). Key features of effective professional development programmes for teachers. *RICERCAZIONE*, *27*.

Putnam, R. T. & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, *29*(1), 4–15.

Robson, C. & McCartan, K. (2016). *Real world research*. Fourth Edition. John Wiley & Sons Ltd.

Sass, W., Boeve-de Pauw, J., Olsson, D., Gericke, N., De Maeyer, S., & Van Petegem, P. (2020). Redefining action competence: The case of sustainable development. *The Journal of Environmental Education*, 1–14.

Scheie, E. & Stromholt, S. (2019). The sustainable backpack: Education for sustainable development through a nationwide professional development programme. *Acta Didactica Norge*, *13*(2), Art. 5.

Scheie, E., Berglund, T., Munkebye, E., Staberg, R. L., & Gericke, N. (2022). Læreplananalyse av kritisk tenking og bærekraftig utvikling i norsk og svensk læreplan. *Acta Didactica Norden*, *16*(2, 4).

Schleicher, A. (2016). *Teaching excellence through professional learning and policy reform: Lessons from around the world. International summit on the teaching profession*. OECD Publishing.

Wiek, A., Bernstein, M.,Foley, R., Cohen, M., Forrest, N., Kuzdas, C., Kay, B., & Withycombe Keeler, L. (2016). Operationalising competencies in higher education for sustainable development. In M. Barth, G. Michelsen, M. Rieckmann, & I. Thomas (Eds.), *Handbook of higher education for sustainable development* (pp .241–260). Routledge.

How outdoor learning can support STEM and sustainability education in initial teacher training

Christina Wolf [1], Luana Monti Jermini[2]

[1]Insitute for Science Teacher Education, St.Gallen University of Teacher Education, Switzerland

[2]Department of Education and Learning, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Locarno, Switzerland

e-mail: Christina.Wolf@phsg.ch

Abstract

Outdoor learning (OL) has been reported to support understanding, knowledge, and motivation in terms of STEM and sustainability education, the latter in the context of environmental education. Pre-service and in-service teachers perceive OL as an authentic context for developing STEM and problem-solving skills in children. In terms of impact on learning and overall well-being, OL could provide additional support for open schooling. However, one repeatedly cited barrier regarding planning and implementing OL with a class is insufficient personal experience and training during initial teacher training. Practitioners and researchers argue that OL should be an integral part of initial teacher training. How to prepare (future) teachers for these approaches? And how can co-creation support this process? We want to address these two questions from the perspective of teacher educators at teacher training universities. Using OL for collaborative discovery of local phenomena provides teachers and teacher educators with a tool for teaching STEM and sustainability education, while also providing one of many opportunities for open schooling. The presentation combines findings from a systematic literature review on OL in teacher training with practical experiences of a teacher educator, who used OL in different teaching settings for STEM and sustainability education.

Keywords

outdoor learning, teacher training, systematic literature review, outdoor journeys

1. Open Schooling and Outdoor Learning (OL)

A report by Make it Open, an EU Horizon 2020 project to support open schooling, tried to define open schooling and characterize some main features to help educators to plan and structure an open schooling project or programme. In the report, Dee Halligan (Director of Forth Together CIC) explains: “Open learning and open schooling are broad terms which describe learning which is ‘open’ in terms of timing, location, teaching roles, instructional methods, modes of access, and any other factors related to learning processes. Most schools already do some level of open learning, through off site trips, on site visits and remote learning.” We intend outdoor learning (OL) has a holistic approach to learning that fits this description perfectly.

We base the definition of OL on the concept of education outside the classroom, which stems from Scandinavia. It means that school subjects are taught in real natural settings such as parks or forests, or in real cultural settings such as schoolyards, museums, or cemeteries (Barfod et al., 2016). The lessons are taught in a pupil-led, teacher-facilitated way based on experiential learning. Physical activity is not a goal, but an integral part of teaching and learning activities. Outdoor learning intends to give children the opportunity to have personal and concrete learning experiences by using their bodies and senses in a real-life environment. Like open schooling, field trips and excursions provide a level of outdoor learning. However, the goal is to have weekly or bi-weekly activities that are regularly integrated into the daily routine and curriculum (Bentsen et al., 2009; Nielsen et al., 2016).

Why is OL relevant for STEM and sustainability education? Many studies have reported that OL enhances understanding, knowledge, and motivation in STEM and sustainability education, the latter in the context of environmental education (Dale et al., 2020; Dettweiler et al., 2017; Mann et al., 2021; Rickinson et al., 2004). Through the 20th century, the focus of outdoor education moved from learners' personal skill development and health care to science education clearly addressing environmental issues. In natural settings, OL authentically addresses the issues of access to natural resources and the learner's place in nature. The OL practices, then, developed within a Western cultural history of opening school learning to consider the social and natural environment in which learning occurs (Wolf et al., 2022). Since the 1990s, several studies reported positive impacts on school students' general health and well-being, connection to nature, and engagement in learning with curriculum-based OL (Bentsen et al., 2022; Lieberman & Hoody, 1998; Lloyd et al., 2018; Marchant et al., 2019; Waite et al., 2016). Because of the growing interest in using nature and the environment for education, the U.S. and the U.K. governments even have incorporated OL into educational strategies and policy developments, e.g., learning for sustainability (Beames et al., 2011; Higgins et al., 2021), and environmental education (North American Association for Environmental Education, 2019). We would like to consider the two following questions: How to prepare (future) teachers for these approaches? And how can co-creation support this process?

2. Outdoor Learning (OL) in initial teacher training

Pre-service (Jegstad et al., 2018; Khwaengmek et al., 2021) and in-service teachers (Christie et al., 2016; Glackin, 2016; Oberbillig et al., 2014) perceive OL as an authentic context for developing STEM and problem-solving skills in children. However, one repeatedly cited barrier regarding planning and implementing OL with a class is insufficient experience and training during initial teacher training. Practitioners and researchers argue that OL and outdoor teaching should be an integral part of initial teacher training (Hammerman, 1960; Kassahun Waktola, 2009; Lindemann-Matthies et al., 2011).

In initial teacher education programs around the world, OL is offered more in science courses – such as biology or science methods – than in other disciplines and sometimes in outdoor or environmental education courses. Therefore, it seems that OL provides a holistic learning and teaching approach in STEM education. Wolf and colleagues (2022) analysed the relevant literature and found that creativity and collaboration are important skills for OL in initial teacher training, both for pre-service teachers (developing those skills) and for teacher educators (using those skills to increase the quality of their teaching). Together with critical thinking and communication, collaboration and creativity form the basic skills for learning in the 21st century, also known as the 4C-based learning model (Binkley et al., 2012; P21, 2015). We support the idea that teachers and teacher educators need the same skills to introduce or promote a new approach into their teaching. As teacher educators, if we are creative or innovative in designing courses, we can also inspire pre-service teachers to be creative and novel in their pedagogical ideas (Dyment et al., 2018). For example, environmental education was found to be a potent source of creativity and continuity for pre-service teachers in curriculum planning for science (Bore, 2006). Collaboration can be diverse and multi-dimensional. Wolf and colleagues (2022) described three dimensions of collaboration in initial teacher training; firstly, between teacher training universities and schools or the community (e.g., Moseley et al., 2002; Kalungwizi et al., 2020, respectively), secondly, within teacher training universities between teacher educators (Bore, 2006), or thirdly, in the context of teaching strategies, e.g., collaborative conversations (Howes et al., 2004).

3. Ways to increase OL practice in initial teacher training

We think that learning and practicing OL as a method and an approach to teaching can help pre-service teachers to become familiar with STEM and sustainability education and in the broader sense with open schooling. The presentation relates to how teacher educators proceed when introducing pre-service teachers to OL in the context of STEM and sustainability education.

Luana Monti Jermini will illustrate the content of a didactic sequence and her pupils’ learning successes. This experience shaped her teacher training activities in STEM, outdoor and sustainability education. In particular, she will explain how “outdoor journeys”, an approach she implemented in a secondary education geography class, support cross-curricular, place-based learning, and how it involves a high degree of student responsibility and the socio-cultural and geo-physical story of students’ local landscape (Beames & Ross, 2010). This will provide an idea of what can be accomplished when educators direct their attention to local phenomena. Furthermore, we confirm to which extent place-based education “develop a readiness for social action, and, with the proper adult guidance, the skills needed for effective democratic participation” (Gruenewald & Smith, 2014, p. xx). We will share more insights on the didactic approach to OL in teacher training, which we believe can strengthen the development of teachers’ professional skills and self-efficacy in STEM and sustainable education.

Research and development projects that foster collaboration between research and teacher training can be a driver for STEM and sustainability education. Increased collaboration within and across universities of teacher education could drive the development of a new curriculum for pre-service teachers that integrates holistic approaches such as OL and focuses on developing the necessary skills.

Acknowledgements

We share results from research and development project “Enabling outdoor-based teaching” at St.Gallen University of Teacher Education. I like to thank the foundations, Mercator Schweiz, Salvia, and SILVIVA under grant number 2019-3474, who support this project and the research team in my institute, who gave me helpful and motivational feedback.

References

Barfod, K., Ejbye-Ernst, N., Mygind, L., & Bentsen, P. (2016). Increased provision of udeskole in Danish schools: An updated national population survey. *Urban For Urban Green*, *20*, 277–281.

Beames, S. & Ross, H. (2010). Journeys outside the classroom. *J. Adventure Educ. Outdoor Learn*, *10*, 95–109.

Beames, S., Higgins, P., & Nicol, R. (2011). *Learning outside the classroom: Theory and guidelines for practice*. Routledge.

Bentsen, P., Mygind, L., Elsborg, P., Nielsen, G., & Mygind, E. (2022). Education outside the classroom as upstream school health promotion: ‘Adding-in’ physical activity into children’s everyday life and settings. *Scandinavian Journal of Public Health*, *50*(3), 303–311.

Bentsen, P., Mygind, E., & Randrup, T. B. (2009). Towards an understanding of udeskole: Education outside the classroom in a Danish context. *Education 3-13*, *37*(1), 29–44.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills*, (pp. 17–66). Springer Netherlands. https://doi.org/10.1007/978-94-007-2324-5_2

Bore, A. (2006). Creativity, continuity and context in teacher education: Lessons from the field. *Australian Journal of Environmental Education*, *22*(1), 31–38.

Dale, R. G., Powell, R. B., Stern, M. J., & Garst, B. A. (2020). Influence of the natural setting on environmental education outcomes. *Environ. Educ. Res*., 26, 613–631.

Dyment, J., Downing, J., Hill, A., & Smith, H. (2018). I did think it was a bit strange taking outdoor education online': Exploration of initial teacher education students' online learning experiences in a tertiary outdoor education unit. *Journal of Adventure Education and Outdoor Learning*, *18*(1), 70–85.

Gruenewald, D. A. & Smith, G. A. (2014). *Place-based education in the global age: Local diversity*. Psychology Press, Taylor&Francis Group.

Hammerman, D. R. (1960). First-rate teachers need firsthand experience: The teacher who would bring meaning and understanding to learning should first be well grounded himself in a variety of direct experiences. *J. Teach. Educ.*, *11*, 408–411.

Higgins, P., Nicol, R., Beames, S., Christie, B., & Scrutton, R. (2021). *Education and culture committee, outdoor learning, submission from Professor Peter Higgin*. https://archive2021.parliament.scot/S4_EducationandCultureCommittee/Inquiries/Prof_Higgins_submission.pdf

Howes, E. V., Jones, K. M., & Rosenthal, B. (2004). Cultivating environmental connections in science teacher education: Learning through conversation. *Teachers and Teaching*, *10*(5), 553–571.

Lieberman, G. & Hoody, L. (1998). Closing the achievement gap. Using the environment as an integrated context for learning. *School K-12.*, *64*. http://www.seer.org/extras/execsum.pdf

Lloyd, A., Truong, S., & Gray, T. (2018). Take the class outside! A call for place-based outdoor learning in the Australian primary school curriculum. *Curriculum Perspectives*, *38*(2), 163–167.

Marchant, E., Todd, C., Cooksey, R., Dredge, S., Jones, H., Reynolds, D., Stratton, G., Dwyer, R., Lyons, R., & Brophy, S. (2019). Curriculum-based outdoor learning for children aged 9 11: A qualitative analysis of pupils' and teachers' views. *PLOS ONE*, *14*(5), e0212242.

Nielsen, G., Mygind, E., Bølling, M., Otte, C. R., Schneller, M. B., Schipperijn, J., Ejbye-Ernst, N., & Bentsen, P. (2016). A quasi-experimental cross-disciplinary evaluation of the impacts of education outside the classroom on pupils' physical activity, well-being and learning: The TEACHOUT study protocol. *BMC Public Health*, *16*(1), 1117.

North American Association & for Environmental Education (NAAEE). (2019). *Professional Development of Environmental Educators: Guidelines for Excellence*. https://cdn.naaee.org/sites/default/files/eepro/products/files/professional_development_lr.pdf

P21 (2015). *The partnership for 21st century learning*. Retrieved from http://www.p21.org/documents/P21_Framework_Definitions.pdf

Parr, M. (2005). Knowing is not enough: We must do! Teacher development through engagement in learning opportunities. *Int. J. Learn.*, *12*, 135–140.

Waite, S., Passy, R., Gilchrist, M., Hunt, A., & Blackwell, I. (2016). *Natural connections demonstration project, 2012-2016: Final report* (NECR215) (Natural England, S. 1–96). Plymouth Institute of Education. http://hdl.handle.net/10026.1/10080

Wolf, C., Kunz, P., & Robin, R. (2022). Emerging themes of research into outdoor teaching in initial formal teacher training from early childhood to secondary education – A literature review. J. Environ. Educ., *53*, 199–220.

Integrated STEAM practice in teacher training: Get to know your rubbish

María Antonia López-Luengo[1], Belén Palop[1,2]

[1] Universidad de Valladolid. Sciences Education, Social Sciences Education and Mathematic Education Department, Segovia, Spain

[2] Universidad Complutense de Madrid. Sciences Education, Social Sciences Education and Mathematic Education Department, Madrid, Spain

e-mail: mariaantonia.lopez@uva.es

Abstract

The primary purpose of this study was to document and interpret a co-teaching experience of the authors to engage prospective elementary teachers in STEAM Education through a sustainability problem. The focus here is upon factors that foster or hinder the competential learning. These are Project Based Learning (PBL); the entry point in a possible connection between climate change and rubbish; the mathematic contents involved (graphics, statistics, proportionality, etc.); and teamwork. The description of the experience put special attention on the formative assessment process as a key point. The results suggest that these prospective elementary school teachers learned approaches to science and mathematics instruction advocated in the national curriculum as well as developed professional competences.

Keywords

STEAM education, environmental education, mathematics education, climate change, prospective elementary teachers

1. Introduction

Integrated STEAM Education (STEAM-Ed) is a methodological approach that promotes the integration of academic subjects through Project Based Learning (PBL). It is becoming a worldwide movement that aims to promote students' core competencies while enhancing and providing them with a deeper understanding of the curriculum (see Belbase et al., 2021, for an updated review on the topic). The importance of promoting the integrated learning of mathematics and science has been claimed for decades (see, e.g., Eurydice report, 2012), and the new Spanish curriculum (Ministerio de Educación y Formación Profesional, 2022) has included the "STEM competence", but there is yet little work on STEAM teacher training and few robust theoretical frameworks (Ortiz-Revilla et al., 2021).

The STEAM-Ed model presents teachers with opportunities to connect the curriculum, not only with other subjects but even within each subject itself. On the other hand, this integration may jeopardize some topics and ideas that need a more abstract setting and/or deliberate practice. To accommodate these two valid, research-based, but opposing views, we need to establish boundaries about when, where, and especially how STEAM-Ed is the appropriate way to develop certain competencies.

In this paper, we focus on how STEAM-Ed can reach Higher Education to build both a more integrated view of the curriculum and the experience of a new methodology that can be applied in the future. The connections arise from the fundamental theme of Environmental Education, which underpins our proposal where students' reflections on this topic are accompanied by the quantitative reasoning and analysis they need to develop as future mathematics educators.

2. What is "Get to know your rubbish"

The models with which we have been educated are the essential reference for the models we will use when we become teachers (Beswick, 2006; Rivero et al., 2011). For this reason, the lack of personal experience of the methodology is one of the factors that make it difficult for teachers to implement PBL in their classrooms. Since we must offer examples and experiences to teachers in training in those educational methodologies that we intend to find in their future practice, we have involved students in an Integrated STEAM proposal. At the same time that the students have gone through this process, they have been introduced to the main aspects of the methodology, always seeking coherence between the experience and the theoretical foundations of STEAM-Ed.

"Get to know your rubbish" is the result of the merger of two electives for 7th semester Teacher Education students. Environmental Education and Mathematics Education meet in a Project Based Learning STEAM approach, where our students gained first-hand experience of the methodology, advancing in the curriculum for both courses while working in an open school setting.

Our PBL proposal starts from the general topic of sustainability, in particular rubbish generation and recycling, to raise awareness of our own effect on the environment. This proposal seeks to answer the question of how to teach preservice teachers to develop and implement open educational projects that allow students to learn science and mathematics in a meaningful, open and hands-on environment. The collaboration between the two lead teachers has allowed us to challenge the students from both disciplines, melting the boundaries between them in terms of the schedule, curriculum, and regular assignments. The authors of the paper sought to be consistent in teaching STEAM by example.

3. Description of the experience (Outline of the presentation)

3.1 Context

The experience took place between February and May 2022, with a small group of 8 trainee teachers in their 7th semester at the Faculty of Education in

Segovia (Spain). Elective subjects of Environmental Education and Mathematics Education, each with a workload for the students of 6 ECTS (approximately 4 face-to-face hours and 6 non-face-to-face hours per week).

3.2 Entry point: The 'Get to know your Rubbish' challenge

The activity began with a news item about the largest landfill in Europe, located in Madrid, less than 100 km from our classroom (Figure 1). During the first 4 weeks the students were introduced to the environmental problems, in particular the greenhouse effect, created by this garbage. The news headline focused on methane emissions. This gave rise to several issues related to the SDGs. Divided into two groups of four students each, they were asked to do further research on this topic as they went through a process of collecting data on the garbage discarded in each of their 8 homes, which was then represented and analyzed. This research was guided by the lead-teachers through formative assessment.

20minutos NACIONAL

Así es el vertedero más grande de España: irregularidades, gases tóxicos y el mayor emisor de metano de Europa

GUILLERMO RODRÍGUEZ / NOTICIA / 07.02.2022 - 17:59H

- A solo 5 kilómetros de Pinto, tiene 659 metros de altura y recibe 800.000 toneladas de residuos al año.
- Ya se ha presentado el plan para añadir 6 macroplantas más, a 3km del municipio, en contra de la voluntad de los vecinos y asociaciones.

Figure 1. News used like entry point of the project (https://www.20minutos.es/noticia/4919992/0/asi-es-el-vertedero-mas-grande-de-espana-irregularidades-gases-toxicos-y-el-mayor-emisor-de-metano-de-europa/)

The students were then challenged to make a contribution that could raise awareness of this issue outside of our classrooms, particularly for primary school teachers or trainee teachers. One group chose to create an art installation to show how much trash the community produced in a day (paper, packaging and mixed waste). The second group, on the other hand, proposed to record video tutorials of various DIY ideas for self-made school supplies from recycled plastic.

The main difficulties for the students were the choice of the specific topic they wanted to address, teamwork and time management. They had to learn to manage this situation of great freedom and autonomy, to which they are less accustomed. At the same time, during the classes, they reviewed the types of plastics, the management of urban waste, the use of spreadsheets, the types of variables and the elaboration and analysis of graphs.

3.3 Development: Making a contribution

During the following 4 weeks, the students had to put their ideas into practice. Each group had a different final product in mind and, therefore, interactions between the two groups decreased during that time and each group focused on different aspects, depending on the chosen objective.

As they had never developed a project before, engineering strategies such as Scrum and Kanban were introduced (Figure 2). Teamwork was - as expected - complicated and the tensions arising from the sudden innovative environment were analyzed and discussed in their dual role as students and future teachers. While the students worked in an adequate and committed manner during these weeks, the classes did not result in clear notes specifying a list of topics to be learned for an exam and, although they knew the competencies to be developed in both courses, the students had an expectation based on the content that caused some trepidation.

At the end of the allotted time, the art installation was displayed at the entrance of the main building of our campus and the video tutorials were promoted on social media (Figure 3). The art installation was surrounded by posters and QR codes explaining the project, providing additional information on waste generation and disposal, and linking to the video tutorials.

3.4 Assessment of the process and learning auto-assessment

Every student reflected about their own learning process in the group; about the PBL methodology, and about the two subjects. They filed a three-column table: in the middle column the learning objectives had been included by the lectures, their project areas for improvement at left and learning notable aspects at right. They wrote things like:

To improve: “It did not occur to me to compare the data with other Spanish citizens to see if our consumption was normal or if we were more or less aware. Also, this should have been extrapolated to other countries”; “To break down activities that may block the main tasks into sub-tasks”; “I would like to get involved with more associations and in the future, as soon as I have more time, I will do so in order to share and give visibility to all that I have learnt”.

Notable aspects: “I understand how and why the process of statistical inference is performed and I think I could replicate it in a similar project”; “Through data collection I have become aware of the amount of waste we generate in our households”; “We integrate the plastic arts in the activity that we propose to carry out in schools, in addition, the assembly of videos, infographics and our social networks, follow a striking model capable of being interpreted in a visual way and that captures the attention of many people while taking care of the aesthetics”.

Figure 2. Students group working

Figure 3. The Education Degree students preparing the art installation

4. Final reflections

The actual implementation of this idea gave us a better understanding of the tensions that arise when first experiencing PBL as a student in Higher Education, as well as the advantages of this integrated approach. We believe the experience has been very positive for us as lead-teachers, since we have also gained practical experience on a methodology that, up to that moment, we had only experienced as mentors of several primary school teachers with whom we have worked for the last 6 years. As well, we learned one from sharing the task in the classroom and we hope to have transferred some of it to the students.

Regarding our students, we think the experience made them improve on all the competences that we had planned to include, of course, to get acquainted with this methodology from a personal viewpoint. The share and formative assessment of the process was key, as well as collaboration between the two groups to raise the goal in time.

It is important to mention here the importance of emotions in learning processes which is being studied especially in the field of science and mathematics. The role of the teacher is very important in this aspect, especially when it comes to detecting problems and providing working tools. The emotions flow through the project. The insecurity at the beginning, the joy at the creativity stage, some frustrating moments for the students that they had to manage, because they couldn't obtain the result they had dreamed of, and finally, joy again when the public exhibition took place, and they received feed-back and questions.

We think that some of the tensions that arose were not originated by the STEAM-Ed or PBL approach themselves, but because of their lack of experience with how competency-based assessment is conducted. It is important to note with respect to this issue that Spanish law has applied this approach since 2006, but its reality is content-based testing and our best students tend to be rather competitive with their grades.

This teaching experience can be transferred to other settings taking into account organizational issues such as having the same set of students in both courses as well as the greater dedication to face-to-face teaching, since co-teaching has been necessary in certain parts of the experience.

Acknowledgements

The authors would like to thank Adrián, Alejandro, Ángela, Celia, David, Lucía H., Lucía T. and Marta for their commitment to learning and collaboration.

This work has been carried out with the support of the Teaching Innovation Project of the University of Valladolid PENSACIENCIA. Rethinking school science. University-school approach. Calls 2021-22 and 2022-23

References

Belbase, S., Bhesh, R. M., Wandee, K., Hassan, T., Munkhjargal, G., & Adeeb, J. (2021). At the dawn of science, technology, engineering, arts, and mathematics (STEAM) education: Prospects, priorities, processes, and problems. *International Journal of Mathematical Education in Science and Technology*, *5*, 1–37. https://doi.org/10.1080/0020739X.2021.1922943

Beswick, K., (2006). Changes in preservice teachers' attitudes and beliefs: the net impact of two mathematics education units and intervening experiences. *School Science and Mathematics*, *106*(1), 36-47. https://doi.org/10.1111/j.1949-8594.2006.tb18069.x

European Commission/EACEA/Eurydice (2012) *Developing key competences at school in Europe: Challenges and opportunities for policy-2011/12. Eurydice Report*. Publications Office of the European Union.

Ministerio de Educación y Formación Profesional (2022). Real Decreto 157/2022, de 1 de marzo, por el que se establecen la ordenación y las enseñanzas mínimas de la Educación Primaria. *Boletín Oficial del Estado*, *52*. https://www.boe.es/eli/es/rd/2022/03/01/157/con

Ortiz-Revilla, J., Sanz-Camarero, M., & Greca, I.M. (2021). Una mirada crítica a los modelos teóricos sobre educación STEAM integrada. *Revista Iberoamericana de Educación*, *87*(2), 13–33 https://doi.org/10.35362/rie8724634

Rivero, A., Azcárate, P., Porlán, R., del Pozo, R. M., & Harres, J. (2011). The progression of prospective primary teachers' conceptions of the methodology of teaching. *Research in Science Education*, *41*(5), 739–769. https://doi.org/10.1007/s11165-010-9188-z

Integrated STEM professional development in interdisciplinary teacher design teams: Teacher self-efficacy profiles using cluster analysis

Seppe Hermans[1], Natacha Gesquiere[2], Francis Wyffels[2], Peter van Petegem[1]

[1]Department of Training and Educational Science, University of Antwerp, Antwerp, Belgium

[2]Department of Electronics and Information Systems, Ghent University, Zwijnaarde, Belgium

Abstract

This study examined teachers' self-efficacy in STEM and computational thinking (CT) and identified distinct profiles based on their self-efficacy ratings. Most teachers recognized the relevance of STEM integration, problem-based learning, computational thinking, and teamwork. However, variations in self-efficacy were observed across specific areas. These findings highlight the need for targeted interventions, particularly for teachers in cluster 3, to enhance self-efficacy in STEM and CT education. Gender differences in profile membership were also noted. This study informs effective professional development programs in these domains.

Keywords

Cluster Analysis, Self-efficacy, STEM, Computational thinking

Introduction

STEM education has gained global attention from ministries of education due to its recognition of the importance of STEM-related competencies for economic growth and global competitiveness (Kennedy & Odell, 2014).Technological advancements and societal changes have driven economic and occupational shifts, leading to the emergence of the fourth industrial revolution, also known as Industry 4.0 (Schleicher, 2019). While the term "STEM" is often used to convey innovation and excitement, it can still be perceived as disconnected subjects (Wang et al., 2011). Integrated STEM education aims to break down the perceived barriers between the four disciplines of science, technology, engineering, and mathematics, fostering students' understanding of the practical applications of STEM to address real-life technical and social challenges. However, implementing integrated STEM education is complex and challenging, as it requires more than just treating different subject areas in parallel (Knipprath et al., 2018). Despite the clear benefits of an integrated STEM approach (Becker & Park, 2011; Roberts, 2013), the implementation in practice does not always align with the intended goals. Creating meaningful connections between STEM disciplines is a challenging task that involves iteratively matching and reorganizing learning goals across different disciplines, determining appropriate sequencing of these goals, and incorporating new learning objectives (Thibaut et al., 2018). Many teachers face obstacles in adopting a more integrated STEM methodology due to these complexities (Margot & Kettler, 2019). Consequently, professional development plays a crucial role in enhancing the quality of STEM education and classroom practices (Loughran, 2014).

Similarly, the integration of computer technology and programming has had a profound impact on society and is considered a vital component for academic and professional success in the technologically advanced 21st century (Shute et al., 2017). Consequently, computational thinking (CT), a complex competency defined as a way of thinking that can be applied to various fields requiring problem-solving skills (Wing, 2008), has been recognized as a critical 21st-century skill (Angeli et al., 2016) and is increasingly being integrated into national curricula across the world (Bocconi et al., 2022; Hsu et al., 2018; Law et al., 2018; Voogt et al., 2015)

Currently the 'iSTEM inkleuren' project aims to translate scientific knowledge on integrated STEM-approaches into practice and builds on research conducted under the 'STEM@School 'project (Knipprath et al., 2018), which provides a framework and lesson materials to facilitate an integrated approach. Because short interventions have been shown to have a limited impact on teaching practices (McConnell et al., 2013), the project adopts a more demand-driven model for teacher professionalisation (i.e., teacher design team, TDT). A TDT can be described as a group of teachers who (re-)design curriculum materials together (Handelzalts, 2009). A distinctive characteristic of TDTs is the sort of design task at hand. This collaborative and inclusive approach allows for the development of innovative and contextually relevant educational practices that align with the needs and interests of the students and the broader community. STEM teacher design teams, through their professionalization efforts, can contribute to the creation and dissemination of open educational resources, collaborative projects, and community engagement initiatives, thereby fostering a more open and interconnected learning environment.

The integration of STEM and CT, like any other innovation, into education is influenced by the attitudes and perceptions of teachers (Davis, 1989). Furthermore, the perceptions and attitudes of teachers towards teaching and learning play a significant role in shaping their instructional practices and impacting the resultant learning outcomes (Tschannen-Moran & Barr, 2004; Tschannen-Moran & Hoy, 2001). As the implementation of CT ad STEM in many education systems is still in its infancy (Bocconi et al., 2022), we want to better understand how teachers that participate in iSTEM training initiative perceive and rate their ability to teach integrated STEM and computational thinking. By doing so, we aim to contribute evidence which could inform any effort of designing efficient training and proper preparation of teachers for the integration of CT in education. To guide our efforts, we formulated the following research questions:

1. What are the self-efficacy profiles of teachers participating in the iSTEM training initiative regarding their ability to teach integrated STEM and computational thinking?
2. How do teachers perceive the relevance of integrated STEM and computational thinking?
3. Are there significant differences in self-efficacy profiles among teachers based on demographics?

Method

Participants

The data for this study was collected at the beginning of the professionalization initiative through an online survey. Participants were 171 secondary school teachers from the Flemish education system who engaged in a professional development trajectory focused on interdisciplinary Teacher Design Teams (TDTs). The TDTs consisted of 4-5 teachers collaborating together. Of the participants, 86 identified as female, and 85 identified as male. The average age of the participants was 45 years, and their average teaching experience was 14 years, ranging from 0 to 30 years. Each TDT was supported by an iSTEM coach who guided the team in incorporating the principles of integrated STEM education. The online survey served as a tool to collect relevant data and insights from the participants regarding their self-efficacy and perceived relevance of STEM and computational thinking in education.

Instrument

To assess teachers' self-efficacy in teaching computational thinking, the questionnaire used in this study was adapted from the TPACK (Technological Pedagogical Content Knowledge) questionnaire developed by (Schmid et al., 2020). To measure teachers' self-efficacy specifically in teaching STEM and computational thinking, the questionnaire items related to subject content and pedagogical knowledge were modified (e.g., "I know the basic theories and concepts of computational thinking ", instead of "I know the basic theories and concepts of my teaching subject"). Additionally, items to measure perceived relevance were included in the questionnaire, drawing from the attitude questionnaire developed by Thibaut et al. (2018). These items assessed teachers' perceived relevance towards STEM integration, problem-based learning, computational thinking, and teamwork. This resulted in a 36-item questionnaire, in which participants were asked to rate each item on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Analysis

To identify different self-efficacy profiles among teachers, a two-step cluster analysis (CA) was employed. Cluster analysis is a statistical method used to group individuals based on similarities across multiple variables. In this analysis, the goal was to identify homogenous groups of teachers without any prior knowledge of the grouping structure, making it a taxonomy analysis. The two-step cluster analysis approach was chosen for this study. This approach consists of two separate steps, with the first step being the pre-clustering phase. During this step, each case is examined individually to construct a cluster features (CF) tree. The log likelihood distance measure is used to determine whether a case should form a new pre-cluster on its own or be merged with other similar cases. After scanning all cases, the resulting pre-clusters are treated as independent entities and serve as the raw data for the next step. The advantage of the two-step clustering approach is that it reduces the size of the distance matrix by basing it on the number of pre-clusters rather than the total number of cases. Additionally, the pre-clustering step automatically standardizes all continuous variables, eliminating the need for separate data transformation steps. The final number of clusters was determined using statistical metrics, such as the silhouette measure of cohesion and separation. This measure assesses how well an object is matched with its own cluster and how poorly it is matched with neighbouring clusters. Scores for the silhouette measure range from -1 to 1, with higher values indicating better cluster fit. After the pre-clustering step, an agglomerative algorithm is used to complete the clustering procedure. For a more detailed description of the methodology, references such as Meila and Heckerman (2013), and Banfield and Raftery (1993) can be consulted. The analysis was performed using IBM SPSS Statistics (Version 28). The scale variables used in the cluster analysis were extracted from the previously mentioned survey.

Results

Our analysis indicated that a three-cluster solution was the most optimal solution for the data, because it minimized the models' Bayesian inference criterion value (BIC) and the ratio of BIC change between adjacent numbers of cluster. Moreover, the model with three clusters was complies with the statistical criteria that each separate cluster should not contain fewer than 7% of the total number of respondents, and a multivariate test should indicate that the cluster solution explains at least 50% of the total variance (Tinsley & Brown, 2000). The number of respondents belonging to each of the clusters exceeded 7% of the total number of respondents (see Table 1). Table 1 also shows the cluster membership for men and women. Moreover, the data contains enough cases (N = 171) to satisfy the cases to variables assumption, as guidelines indicate a minimum of 10 cases per independent variable (Schwab, 2002). A graphic representation of the profile cluster can be found in Figure 1.

Table 1 Cluster profiles

	N_{total}	N_{male}	N_{female}	M_{age}	Self-efficacy					Perceived relevance			
					STEM content	STEM pedagogy	CT content	CT pedagogy	CT-STEM pedagogy	STEM integration	PBL	CT	Team work
Cluster 1	44	19	25	41	4,26	4,10	4,10	3,76	3,97	4,47	4,41	4,42	4,46
Cluster 2	84	38	46	48	3,72	3,28	3,28	2,88	3,23	3,97	4,03	4,01	4,14
Cluster 3	43	28	15	43	2,93	1,97	1,97	1,85	1,88	3,73	3,92	3,83	3,92
All	171	85	86	44	3,66	3,29	3,16	2,85	3,08	4,04	4,10	4,07	4,17

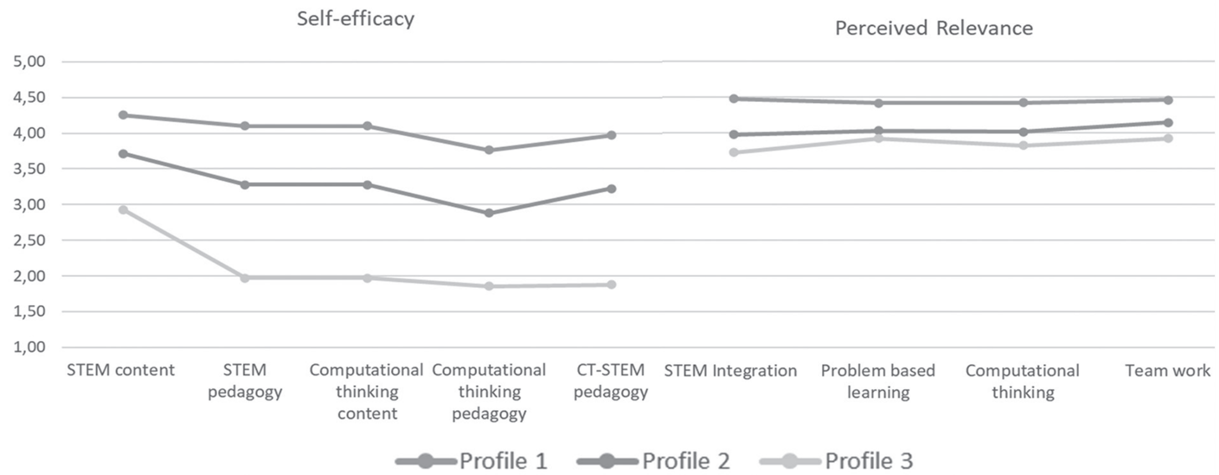


Figure 1 Profiles identified in this study

In the following section, we will present the characteristics of each cluster in detail. As the teachers' perceived relevance towards STEM integration, problem-based learning, computational thinking, and teamwork in each cluster differs marginally, we will exclude it from this comparison. We do however note regarding our second research question that overall, most teachers perceive STEM integration (*M*= 4.04, *SD*= 0.55), problem-based learning (*M*= 4.10, *SD*=0.56), computational thinking (*M*= 4.07, *SD*=0.48), and teamwork (*M*= 4.17, *SD*=0.65) as relevant educational practices.

Cluster 1 (*N* = 44, 26%) can be considered the most favourable profile cluster as teachers rate there self-efficacy regarding STEM content (*M*= 4.26, *SD*= 0.48), STEM pedagogy (*M*= 4.10, *SD*= 0.52), CT content (*M*= 3.76, *SD*= 0.51), CT pedagogy (*M*= 3.76, *SD*= 0.56), and CT-STEM pedagogy (*M*= 4.47, *SD*= 0.48) higher than teachers in cluster two and three. This cluster consists of 19 male (22%) and 25 female (29%) teachers.

Cluster 2(*N* = 84, 49%) (*N* = 43, 25%) can be considered a good but average profile cluster as teachers rate there self-efficacy regarding STEM content (*M*= 3.72, *SD*= 0.48), STEM pedagogy (*M*= 3.28, *SD*= 0.59), CT content (*M*= 3.28, *SD*= 0.62), CT pedagogy (*M*= 2.88, *SD*= 0.51), and CT-STEM pedagogy (*M*= 3.23, *SD*= 0.50) lower than teachers in cluster one but higher than teachers in cluster three. This cluster consists of 38 male (45%) and 46 female (53%) teachers.

Cluster 3 (*N* = 43, 25%) can be considered the least favourable profile cluster as teachers rate there self-efficacy regarding STEM content (*M*= 2.93, *SD*= 0.92), STEM pedagogy (*M*= 1.97, *SD*= 0.93), CT content (*M*= 1.97, *SD*= 0.79), CT pedagogy (*M*= 1.85, *SD*= 0.77), and CT-STEM pedagogy (*M*= 1.88, *SD*= 0.67) lower than teachers in cluster one and two. This cluster consists of 28 male (33%) and 15 female (17%) teachers.

Discussion and conclusion

The present study aimed to identify different profiles of teachers' self-efficacy in teaching STEM and computational thinking (CT). The results revealed three distinct clusters, each representing a different profile of self-efficacy. It is important to note that the perceived relevance towards STEM integration, problem-based learning, computational thinking, and teamwork did not significantly differ among the clusters. The findings suggest that teachers with profiles in Cluster 3 may have the most to gain from interventions aimed at improving their self-efficacy in teaching STEM and computational thinking. Targeted professional development programs could be designed to address the specific needs and challenges faced by teachers in this cluster. Gender differences were observed in profile membership, with more male teachers in Cluster 3 compared to the other clusters. This finding highlights the importance of considering gender-specific factors when designing interventions and support mechanisms to enhance self-efficacy in STEM and computational thinking among teachers.

References

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 computational thinking curriculum framework: Implications for teacher knowledge. *Journal of Educational Technology & Society*, *19*(3), 47–57.

Banfield, J. D., & Raftery, A. E. (1993). Model-based Gaussian and non-Gaussian clustering. *Biometrics*, 803–821.

Becker, K. H., & Park, K. (2011). Integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A meta-analysis. In (Vol. 12).

Bocconi, S., Chioccariello, A., Kampylis, P., Dagienė, V., Wastiau, P., Engelhardt, K., Earp, J., Horvath, M., Jasutė, E., & Malagoli, C. (2022). Reviewing computational thinking in compulsory education: state of play and practices from computing education.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*(3), 319–340.

Handelzalts, A. (2009). *Collaborative curriculum development in teacher design teams*. University of Twente.

Hsu, T.-C., Chang, S.-C., & Hung, Y.-T. (2018). How to learn and how to teach computational thinking: Suggestions based on a review of the literature. *Computers & Education*, *126*, 296–310.

Kennedy, T., & Odell, M. R. L. (2014). Engaging students In STEM education. *Science Education International*, *25*, 246–258.

Knipprath, H., Thibaut, L., Buyse, M. P., Ceuppens, S., Loof, H. D., Meester, J. D., Goovaerts, L., Struyf, A., Pauw, J. B. D., Depaepe, F., Deprez, J., Cock, M. D., Hellinckx, L., Langie, G., Struyven, K., Velde, D. V. d., Petegem, P. V., & Dehaene, W. (2018). STEM Education in Flanders: How STEM@school aims to foster STEM literacy and a positive attitude towards STEM. *IEEE Instrumentation & Measurement Magazine*, *21*(3), 36–40.

Law, N., Woo, D., & Wong, G. (2018). *A global framework of reference on digital literacy skills for indicator 4.4. 2*. Unesco Institute for Statistics.

Loughran, J. (2014). Professionally developing as a teacher educator. *Journal of Teacher Education*, *65*(4), 271–283.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*(1), 1–16.

McConnell, T. J., Parker, J. M., & Eberhardt, J. (2013). Problem-based learning as an effective strategy for science teacher professional development. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *86*(6), 216–223.

Meila, M., & Heckerman, D. (2013). An experimental comparison of several clustering and initialization methods. arXiv preprint arXiv:1301.7401.

Roberts, A. (2013). STEM is here. Now what? *Technology and Engineering Teacher*, *73*(1), 22.

Schleicher, A. (2019). PISA 2018: Insights and Interpretations. OECD.

Schmid, M., Brianza, E., & Petko, D. (2020). Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK. xs) and comparing the factor structure of an integrative and a transformative model. *Computers & Education*, *157*, 103967.

Schwab, J. A. (2002). Multinomial logistic regression: Basic relationships and complete problems. In.

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, *22*, 142–158.

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Velde, D., Van Petegem, P., & Depaepe, F. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education*, *3*.

Tinsley, H. E. A., & Brown, S. D. (2000). Ha*ndbook of applied multivariate statistics and mathematical modeling*. Academic Press.

Tschannen-Moran, M., & Barr, M. (2004). Fostering student learning: The relationship of collective teacher efficacy and student achievement. *Leadership and Policy in Schools*, *3*(3), 189–209.

Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, *17*(7), 783–805.

Voogt, J., Laferriere, T., Breuleux, A., Itow, R. C., Hickey, D. T., & McKenney, S. (2015). Collaborative design as a form of professional development. *Instructional Science*, *43*(2), 259–282.

Wang, H.-H., Moore, T., Roehrig, G., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice.

Wing, J. (2008). Computational thinking and thinking about computing. Ph*ilosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences*, *366*, 3717–3725.

Mathematical modelling for critical citizenship

Jimbo Juanito B. Villamor[1,2], Catherine P. Vistro-Yu[1]

[1]Ateneo de Manila University, Philippines

[2]Surigao del Norte State University, Philippines

email: ajimbo.villamor@obf.ateneo.edu

Abstract

This ongoing mixed-methods research investigates how mathematics teachers could help facilitate the development of students' mathematical understanding through mathematical modelling. It explored the potentiality of mathematical modelling tasks themed with issues on solid waste management in unpacking critical citizenship among mathematics students. Results showed that the designed mathematical modelling tasks centered on solid waste management problems facilitate the development of mathematical understanding and critical citizenship of students. By using such tasks, mathematics teachers can learn to become more concerned about their natural and social environment, while helping students come up with strategies for a sustainable living. This suggests that mathematical modelling activities that explore environmental issues could be a good avenue for students to gradually become critical members of society.

Keywords

critical citizenship, mathematical modelling, mixed-methods research in mathematics education, solid waste management issues

1. Background and rationale of the study

Life has become more daunting than ever with the accelerated globalization and rapid technological advancement. This reality calls education sectors to revolutionize teaching and learning approaches in order to help individuals become ready for their future. For this reason, the Organization for Economic Cooperation and Development (OECD) has framed competencies necessary for one to thrive in this "volatile, uncertain, complex and ambiguous (VUCA) world" (OECD 2030 Learning Framework, 2018, p.10). These competencies are expected to help students become functional, responsive, resilient, responsible, concerned, reflective and critical citizens.

Mathematics education experts have long encouraged mathematics teachers to provide learning tasks that highly engage students in solving problems and developing reasoning abilities. These tasks should help mathematics teachers facilitate students' search for meaningful connections between mathematical concepts and the world, and should also allow teachers to pose questions that will help in advancing students' reasoning skills (National Council of Teachers of Mathematics, 2014). Hence, for students to possess the competencies for sustainable future, teachers have to be equipped with the knowledge and skills for innovative and creative teaching and learning, evident from their designed learning tasks. This innovative learning engagement may be possible by integrating mathematical modelling approach. Mathematical modelling is interdisciplinary in nature and helps students make mathematical descriptions of meaningful real-life situations (Erbas et al., 2014) to make mathematics classes more meaningful, dynamic, and relevant.

In this study, the mathematical modelling tasks designed by the researchers were centered around solid waste management issues. Such tasks connect mathematics and environmental education, and exhibit bringing to life the principle that Science, Technology, Engineering and Mathematics (STEM) education should provide logical and authentic connections between and across the individual STEM disciplines (Principle 2, STEM4: The power of collaboration for change, 2020). Thus, designing such modelling tasks paves the way to not only assist students in enhancing their mathematical understanding, but also in strengthening their environmental education, in particular, knowledge on climate change, sustainable development, and sustainable solutions. This understanding helps students become more concerned about their environment, allowing them to participate in framing response mechanisms and strategies towards mitigating this environmental issue, at the community level, and thereby gradually attain a sustainable future.

2. Theoretical underpinnings

This study was anchored on the theoretical perspectives of critical mathematics education (CME), which support addressing social development issues and views of mathematics education as a contributor towards critical citizenship (Skovsmose & Niss, 2008). In particular, mathematics education for critical citizenship was used to ascertain that students are actively engaged as critical members of the society. This study also considered O'Donnell's (2018) transdisciplinary lesson and unit framework in organizing mathematical modelling tasks on solid waste management.

The idea that mathematics education develops critical citizenship provides an avenue for students to become empowered, get involved, and be engaged with a community or social issue (Skovsmose, 1994; OECD 2030 Learning Framework). It helps students become active citizens (Skovsmose, 1994), which means having a developed critical thinking and decision-making skills to make informed decisions (Zeidler & Nichols, 2009; Maass et al., 2019), and one's ability to form sound opinions, ethical or social reasoning (Maass et al., 2019). As critical citizens, individuals discern their roles as critical members of society conceiving of actions that will make a difference (Skovsmose, 1992, 1994). The use of mathematics education for critical citizenship enhances student's literacy and numeracy skills (Skovsmose, 1994; Jazby, 2017) by applying mathematical understanding in authentic problems (Maass et.al., 2019), helps in one's participation in the understanding and transformation of the society (Giroux, 1988, as cited by Skovsmose, 1992), allows one to master specific mathematical skills and particular forms of knowledge (Giroux, 1988, as cited by Skovsmose, 1992), and improvement of students' civic competence (Skovsmose, 1994) by making them aware of their community obligations (Gramsci, 1989, as cited by Skovsmose, 1992).

3. Methods

This study employed a mixed-method research design from the advocacy and participatory worldview. The quantitative part investigated the students' level of performance in doing the mathematical modelling task while the qualitative part explored how students framed solutions in mitigating solid waste issues in school. Purposive sampling was used in determining the 31 student-participants, who are currently enrolled in solid mensuration course. This study was conducted in one of Philippine islands, categorized as a protected area by the Department of Environment and Natural Resources (DENR), at the same time, a tourist destination classified by the Department of Tourism (DOT).

For this paper, we will present the results of implementing only one modelling task. This mathematical modelling task is an application problem on volumes of prisms and was allotted for two hours. Five groups of students were formed; four groups were composed of six members, while the other one group was composed of seven. The mathematical modelling task was assessed using the suggested features from the Guidelines for Assessment & Instruction in Mathematical Modelling Education (GAIMME, 2019) collaboratively designed by the Consortium for Mathematics and Its Applications (COMAP), Society for Industrial and Applied Mathematics (SIAM), National Council of Teachers of Mathematics (NCTM), and The Moody's Foundation. The student scores from performing the task were analyzed using the mean, standard deviation, and t-test. The overall class performance was described using the assessment guidelines of the Philippines' Department of Education as specified in DO 8, s. 2015. The students' suggestions for potential solutions in mitigating solid wastes were analyzed and interpreted using a thematic analysis.

4. Results and discussions

The students' mathematical modelling performance was assessed in the context of building the model which focused on (1) making assumptions and acknowledging limitations; (2) defining variables and identifying parameters; (3) solutions focused on the use of meaningful mathematics; (4) analysis and assessment of model; and (5) writing style and organization (GAIMME, 2019). Since the designed mathematical modelling task addressed solid waste management issue in a research environment, the researchers added the possible impact of the proposed solution as another feature. Framing of the potential environmental solution is deemed to indicate how students actively engaged as critical members of the society.

Table 1. Group performance in mathematical modelling

Student group	**Total score** (Highest possible points: 25)	**Percentage score**	**Qualitative description**
Group A	13	52%	Did not meet expectations
Group B	20	80%	Passing performance
Group C	19	76%	Passing performance
Group D	14	56%	Did not meet expectations
Group E	12	48%	Did not meetexpectations

Legend: 75% and above: Passing performance; Less than 75%: Did not meet expectations

The group performances in mathematical modelling were classified according to their percentage scores. The levels, anchored on the K-12 Assessment Guidelines with minimal modification are: 'passing performance' and 'did not meet expectations.' From Table 1, two of the five groups have achieved 'passing performance in doing the mathematical modelling task' while three of them achieved 'did not meet expectations.'

For convention in this study, those with passing performance belong to the upper group, those who did not meet expectations, the lower group. The students' class performances in doing the mathematical modelling task were further analyzed using the descriptors of GAIMME (2019) as ideal, satisfactory, needs improvement, and incomplete. Overall, the class performance in doing the mathematical modelling task as shown in Table 2 was *satisfactory*; the upper group had an ideal performance while the lower group, *satisfactory*. Both groups had ideal class performances in making assumptions and acknowledging limitations, defining variables and identifying parameters, and in writing style and organization. The upper group had a *satisfactory* class performance in making use of meaningful mathematics in the model and in proposing potential solutions to the problem, while the lower group *needs improvement* in these areas. The performance of both groups in the area of analysis and assessment of model *needs improvement*.

From the reported average scores, the groups' performances according to the features of the mathematical modelling tasks varied extensively. To determine whether these performances differed significantly, a t-test was performed. Table 3 presents the differences in class performance in mathematical modelling using the t-test. The t-test for making assumptions and acknowledging limitations and analysis and assessment of model could not be performed because the average scores were the same. Variances are approximately equal in the remaining features of mathematical modelling as indicated by the Levene's test for equality of variances ($p = 0.53$, $p = 0.724$). This means that the distribution of the average scores in these features obtained by the upper group is similar in shape to the distribution of the average scores obtained by the lower group.

Table 2. Average class performance in mathematical modelling

Features of mathematical modelling task	**Highest possible score**	**Average score**		**Std. deviation**	**Qualitative description**
Building the model: Make assumptions and acknowledge limitations	3.00	Upper group	3.00	0.00	Ideal
		Lower group	3.00	0.00	Ideal
		Overall	3.00	0.00	Ideal
Building the model: Define variables and identify parameters	3.00	Upper group	3.00	0.00	Ideal
		Lower group	2.67	0.58	Ideal
		Overall	2.83	0.29	Ideal
Solution: Model uses meaningful mathematics	4.00	Upper group	3.00	0.00	Satisfactory
		Lower group	1.33	0.58	Needs improvement
		Overall	2.17	0.58	Needs improvement
Analysis & assessment of model	5.00	Upper group	3.00	0.00	Satisfactory
		Lower group	1.00	0.00	Needs improvement

Features of mathematical modelling task	Highest possible score	Average score		Std. deviation	Qualitative description
		Overall	2.00	0.00	Needs improvement
Writing style & organization	5.00	Upper group	4.00	0.00	Ideal
		Lower group	3.33	0.58	Ideal
		Overall	3.67	0.29	Ideal
Possible impact of the proposed solutions	5.00	Upper group	3.50	0.71	Satisfactory
		Lower group	1.67	0.58	Needs improvement
		Overall	2.59	0.65	Satisfactory
		Upper group	3.25	0.12	Ideal
Average		Lower group	2.60	0.46	Satisfactory
		Overall	2.93	0.29	Satisfactory

Legend:

3-point score: Ideal (2.50-3.00), Satisfactory (2.00-2.49), Needs improvement (1.00-1.99), Incomplete (0.00-0.99)

4-point score: Ideal (3.25-4.00), Satisfactory (2.50-3.24), Needs improvement (0.75-2.49), Incomplete (0.00-0.74)

5-point score: Ideal (3.75-5.00), Satisfactory (2.50-3.74), Needs improvement (1.25-2.49), Incomplete (0.00-1.24)

Further, the students' solutions using meaningful mathematics in modelling and the possible impact of the proposed solutions were statistically different between the upper and lower groups. This means that the upper group had significantly better performance than the lower group in making use of meaningful mathematics (T=3.873, *p*=0.030) and in proposing sustainable solutions addressing solid waste issues (T=3.220, *p*=0.049). Interestingly, students who are performing better in making assumptions and acknowledging limitations, defining variables and identifying parameters, and making use of meaningful mathematics in modelling were able to frame potential solutions in mitigating solid waste problems. This indicates that those who have good performances in mathematical modelling show some tendencies for strengthening their participation as a critical member of society. These groups suggested using alternative ways in reducing solid wastes aside from using compost pit and landfills. These included: reusing plastic wastes for profitable use and, creating rectangular trash bins inside the school campus to segregate biodegradable, nonbiodegradable, and hazardous wastes.

The mathematical modelling task designed for volume of prisms realizes the usefulness of mathematics education for critical citizenship. While students performed mathematical calculations, they were also asked to suggest solutions to mitigate the solid wastes issues in their school. Students' responses were analyzed using a thematic analysis.

Table 3. Differences on class performance in mathematical modelling using *t*-test

Features of mathematical modelling task	**Levene's test for equality of variances**		**t-test for equality of mans**		**Interpretation**
	F	**p-value**	**T**	**p-value**	
Building the model: Define variables and identify parameter	9.600	.053	.775	.495	Not sgnificant
Solution: Model uses meaningful mathematics	9.600	.053	3.873	.030	Significant
Writing syle & organization	9.600	.053	1.549	.219	Not significant
Possible impact of the proposed solution	.150	.724	3.220	.049	Significant

Responses showed that the mathematical modelling task provides an avenue for students to become empowered, get involved, and be engaged with a community or social issue (Skovsmose, 1994; OECD 2030 Learning Framework). From the suggested alternative solutions to manage solid waste problems, students displayed their potential to become active citizens (Skovsmose, 1994) by developing critical thinking and decision-making skills to make informed decisions (Zeidler & Nichols, 2009; Maass et al., 2019), developing creativity and critical thinking skills (Maass et al., 2019), forming sound opinions, ethical or social reasoning (Maass et al., 2019). The students' suggestions help them discern their roles as critical members of society and conceive of actions that will make a difference (Skovsmose, 1992, 1994). The mathematical modelling task provided was able to enhance student's literacy and numeracy skills (Skovsmose, 1994; Jazby, 2017) by applying mathematical understanding in authentic problems (Maass et al., 2019), and allowing students to participate in the understanding and transformation of the society and master specific mathematical skills and particular forms of knowledge (Giroux, 1988, as cited by Skovsmose, 1992), and improves students' civic competence (Skovsmose, 1994) by making them aware of their community obligations (Gramsci, 1989, as cited by Skovsmose, 1992).

5. Conclusion and Recommendations

The designed mathematical modelling task centered around solid waste management problems facilitates the development of mathematical understanding and critical citizenship of students. This indicates that such kind of mathematical modelling task creates a dynamic and meaningful connection of mathematics to the community. By using such tasks, mathematics teachers can learn, themselves, to become more concerned about their natural and social environment, while helping students come up with strategies for a sustainable living. Their perspectives in teaching mathematics will be broadened, allowing them to teach mathematics not only within the four walls of the classroom, but also utilizing the community as a learning laboratory. This suggests that mathematical modelling activities which explored environmental issues can be a good avenue for students to gradually become critical members of the society. Teachers who wished to venture in such undertaking will not only develop students' understanding of mathematical concepts but also of competencies for critical citizenship. Mathematics teachers may consider integrating mathematical modelling activities as performance tasks to deepen students' understanding of mathematical concepts and ideas.

Acknowledgements

The authors would like to thank the Department of Science and Technology – Science Education Institute (DOST-SEI) through the Capacity-Building Program for Science and Mathematics Educators (CBPSME) grant for making it possible for the first author to pursue graduate studies. Parallel gratitude is extended to Surigao del Norte State University for allowing the first author on full-time study, and to Ateneo de Manila University for honing the research skills of the first author. Esteemed thanks is also expressed for Siargao Island Protected Landscapes and Seascapes (SIPLAS), Schools Division Office of Siargao – Department of Education, and Siargao National Science High School for allowing the researchers conduct this study.

References

Erbas, A. K., Kertil, M., Çetinkaya, B., Çakiroglu, E., Alacaci, C., & Bas, S. (2014). Mathematical modeling in mathematics education: basic concepts and approaches. *Educational Sciences: Theory and Practice*, *14*(4), 1621–1627.

English, L. D. (2016). Advancing mathematics education research within a STEM environment. *Research in mathematics education in Australasia 2012-2015*, 353–371.

Hernandez-Martinez, P. & Vos, P. (2018). "Why do I have to learn this?" A case study on students' experiences of the relevance of mathematical modelling activities. *ZDM*, *50*(1), 245–257.

Jazby, D. (2017). *Is mathematics education worthy? From mathematics for critical citizenship to productivity growth*. Mathematics Education Research Group of Australasia.

Kaiser, G. (2020). Mathematical modelling and applications in education. In *Encyclopedia of mathematics education*, (pp. 553–561).

Maass, K., Doorman, M., Jonker, V., & Wijers, M. (2019). Promoting active citizenship in mathematics teaching. *ZDM*, *51*, 991–1003.

OECD, *2030 Learning Framework.*

O'Donnell, C. (2021). *Discover, Understand, Act: A STEM education framework for empowering youth to address the global goals*. Diplomatic Courier, UNGA 2021 Special Print Edition.

Skovsmose, O. & Niss, M. (2008). Critical mathematics education for the future. *In ICME-10 Proceedings: Proceedings of the 10th International Congress on Mathematical Education*. IMFUFA, Roskilde University.

Skovsmose, O. (1994). Towards a critical mathematics education. *Educational Studies in Mathematics*, *27*(1), 35–57.

Skovsmose, O. (1992). Democratic competence and reflective knowing in mathematics. *For the Learning of Mathematics*, *12*(2), 2–11.

Zeidler, D. L. & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, *21*, 49–58.

Open maths meets sustainability

A model for integrating sustainability and mindset into mathematics education

Marloes van Hoeve[1,2], Greg Alpár[3,4]

[1]Hogeschool Utrecht, the Netherlands, [2]Goois Lyceum, Bussum, the Netherlands

[3]Open Universiteit, the Netherlands, [4]Radboud University, the Netherlands

e-mail: marloes.vanhoeve@hu.nl

1. Introduction

The urgency of the climate crisis is evident in various media sources. For instance, according to the Intergovernmental Panel on Climate Change, "biodiversity loss, overall unsustainable consumption of natural resources, land and ecosystem degradation, rapid urbanisation, human demographic shifts, social and economic inequalities and a pandemic" can all be related to climate change (IPCC, 2022). As a result, it is imperative to seek new sustainable approaches to address these challenges. In the coming decades, significant innovation will be necessary, with emerging technologies playing a vital role in mitigating climate change and adapting to its existing impacts. STEM subjects, particularly mathematics, form the foundation for many of these innovative solutions. Mathematics facilitates problem understanding, modelling complex situations, computer-based problem-solving, and other technical applications. Engaging current students in these novel ideas and approaches is crucial for addressing the climate crisis effectively.

Nevertheless, mathematics, an abstract subject encompassing numerical and spatial relationships fundamental to various scientific and engineering disciplines, continues to be predominantly taught in a traditional manner, with students following instructions and prescribed methods. Insufficient emphasis is placed on teaching students *how to learn mathematics effectively* and *how to develop their own capabilities*. Additionally, there is a lack of connection between the pressing global challenges and the potential contributions of mathematics in solving them. Educational resources often lack relevant and meaningful assignments that incorporate environmental and sustainability contexts. To enhance the current state of education, it is crucial for teachers to be adequately prepared for engaging discussions about real-world issues and promoting the application of mathematics in contexts related to sustainability (Moreno-Pino et al., 2021).

This paper proposes a novel model that examines the interplay between growth mindset, mathematics, and sustainability. Firstly, we provide a background on the teaching and learning of mathematics with a growth mindset. Next, we present our model, outlining its key components and mechanisms, and investigate the reciprocal effects of a growth mindset, mathematics, and sustainability on one another, emphasizing their interconnected nature. Finally, we discuss the implications of our model and its relation to practical ideas for mathematics education, in the context of sustainability, drawing insights from existing literature. By investigating these relationships, our model aims to contribute to the advancement of effective mathematics education practices that promote sustainability.

2. Open maths

Carol Dweck's mindset theory (Dweck, 2017) introduces the concepts of fixed and growth mindsets, which are influenced by various factors and can change over time. Fixed mindsets, characterized by the belief in fixed intelligence and talent, lead individuals to avoid challenges and prioritize self-preservation. In contrast, growth mindsets view intelligence and abilities as malleable, motivating individuals to embrace challenges and persist in the face of obstacles. Dweck emphasises the role of beliefs about one's abilities and highlights the importance of effort and resilience in achieving success. By understanding and adopting a growth mindset, individuals can transform their beliefs. The theory underscores the significance of embracing challenges, learning from mistakes, and fostering a belief in personal growth through effort and practice. Adopting a growth mindset can impact persona development, learning, and success in various domains of life.

Neuroplasticity defines the ability of the brain to adapt and change. It involves various mechanisms such as volume changes, the formation of new neural pathways, and alterations in the myelin sheath that surrounds nerve fibers (Dan, 2019). Understanding the relationship between mindset and neuroplasticity is crucial for educators. When teachers and students learn about how the brain functions, including the capacity of neurons to form new connections and acquire new knowledge, it can foster trust in the learning process and enhance learning success (Sarrasin, 2018).

An intriguing aspect is that when we approach learning with a growth mindset, wherein we believe that abilities can be developed through effort, our brain's neuroplasticity is more pronounced. When we make mistakes while having a growth mindset, our neurons form more new connections compared to when we have a fixed mindset. This insight highlights the importance of cultivating a growth mindset in both teachers and students, as it not only promotes a positive attitude towards learning and embracing challenges but also optimizes the brain's capacity for neuroplasticity. By recognizing the potential for change and improvement, individuals can harness the power of neuroplasticity to enhance their learning and cognitive development.

The approach of teaching mathematics with a growth mindset emphasizes the belief that both the teacher and the learner have the potential to improve their mathematical abilities. This perspective, advocated by researchers like Boaler (2015), fosters greater student engagement in their own development and in the subject itself. Students establish a personal connection with mathematics by actively reflecting on abstract structures, quantities, and visuals.

In Open Maths (Alpár and van Hoeve, 2019), an adaptation of this approach, students are encouraged to make connections between different theoretical concepts and real-world applications. They engage in various assignments that allow them to explore and practice new strategies with a sense of curiosity and discovery (Foster, 2013; Kaplinsky, 2020). Importantly, the learning environment is a safe space where making mistakes is viewed as a valuable part of the learning process. Students are also encouraged to collaborate and work together, as this enables the sharing of different perspectives and experiences.

By adopting a growth mindset in mathematics education, students become more actively involved in their learning journey. They develop a deeper understanding of mathematical concepts and enhance their problem-solving skills. The Open Maths approach nurtures a positive and inclusive learning environment that supports students in embracing challenges and reaching their full mathematical potential.

Applying Open Maths in the context of sustainability offers significant benefits. By incorporating a growth mindset perspective, students are encouraged to explore the interconnectedness of mathematics and sustainability, fostering a deeper understanding of how mathematical concepts can be applied to real-world environmental and social challenges. This approach of mathematics education empowers students to comprehend the complexity of sustainability issues, evaluate potential solutions, and actively participate in solving environmental problems. The Realistic Mathematics Education (RME) movement (Phan et al., 2022) provides practical techniques for integrating sustainability themes as a realistic context. To make this more specific, we introduce a model in the following sections that helps implementing strategies to foster a growth mindset, connect mathematics to sustainability, and prepare students to shape a sustainable future.

3. Our model: The triangle of growth mindset, mathematics, and sustainability

We introduce our triangular model depicting the significant interconnections between growth mindset, mathematics, and sustainability; see Figure 1. A growth mindset cultivates students' openness and trust in facing the challenges of the future, including those in the realm of mathematics. Mathematics, in turn, plays a crucial role in enhancing understanding of sustainability issues and offering valuable insights into potential solutions.

In the model, the relationships are depicted as arrows. By adopting a growth mindset, students develop a belief in their capacity to learn and improve, enabling them to embrace mathematical challenges with resilience and enthusiasm. This mindset fosters a positive learning environment where students are motivated to explore complex mathematical concepts and develop problem-solving skills necessary for addressing sustainability challenges.

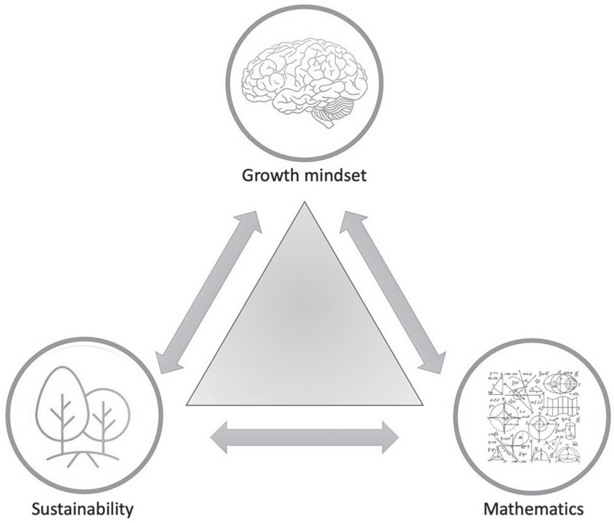


Figure 1. Positive exchange in the triangle of a growth mindset, mathematics, and sustainability

Mathematics serves as a powerful tool for comprehending and analysing sustainability problems. It provides a language and framework to examine intricate relationships and patterns, enabling individuals to gain a deeper understanding of the interconnectedness of environmental, social, and economic systems. Through mathematical modelling, analysis, and data interpretation, students can explore the impacts of human actions on the environment and identify potential pathways towards sustainability.

Additionally, mathematics offers insights into solutions for sustainable development. By applying mathematical concepts, such as optimisation, probability, and systems thinking, students can generate innovative approaches to mitigate climate change, promote renewable energy adoption, optimize resource allocation, and design sustainable urban systems, among other areas. Mathematics empowers students to evaluate the effectiveness of different strategies and make informed decisions based on quantitative analysis and evidence.

4. Our model put in practice

Several papers discuss possible ways to include sustainability in mathematics education (Prieto-Saborit et al., 2022). While most of them require considerable adjustments in the current curriculum, Hamilton and Pfaff (2014) suggest foundational yet practical ideas in this context, calling for the nourishment of “an educated citizenry.” Building on their ideas, we establish meaningful connections between each of their five principles and our triangular model, further enriching our understanding of the interplay among a growth mindset (G), mathematics (M), and sustainability (S) in the educational context.

- Principle 1, S → M: By teaching *mathematics in context* by integrating sustainability-oriented content and introducing "global realities" into mathematics instruction, students recognise the vital role of mathematics in addressing real-world sustainability challenges. This establishes a clear and direct connection from sustainability to mathematics in our model.
- Principle 2, S → M: Including *real-life problems* in mathematics instruction creates a direct relationship from sustainability to mathematics in our educational context. Urgent examples that highlight the relevance of mathematical theory and techniques prompt students to think beyond abstract concepts and engage in discussions about practical applications.
- Principle 3, M → S: Emphasising "designing the future" and *teaching the tools of complexity, systems thinking, and design thinking* demonstrates a direct relationship from mathematics to sustainability within our model. By equipping students with these valuable tools, they can explore new areas and draw deep connections between mathematical concepts and sustainability challenges.
- Principle 4, S → G: Acknowledging *the ethical and psychological aspects* of sustainability issues and engaging in discussions with students about their findings and learning process promotes a relationship from sustainability to a growth mindset within our model. By reflecting on the ethical implications and emotional dimensions (moods, feelings, attitudes, etc.) of sustainability, students develop a deeper understanding of the personal and societal impacts of their actions.
- Principle 5, M&G → S: Teaching *specific mathematical and broader skills* that empower students to become catalysts and leaders of change establishes a relationship from mathematics and a growth mindset to sustainability within our model. By equipping students with the necessary mathematical skills and wider competencies, such as critical thinking, problem-solving, and communication, they are empowered to actively contribute to addressing sustainability challenges.

In summary, understanding the five principles of Hamilton and Pfaff within our general model empowers students to actively shape a more sustainable future through their mathematical understanding, a growth mindset, and their actions.

To demonstrate how the model can be applied in the classroom, we show an example of the integration of sustainability and mathematics education in exploring the "Impact of your clothing". Starting with a graph or table that presents relevant data on transport costs, CO_2 output, climate impact, and water usage, students are prompted with open-ended questions such as "What do you notice?" or "What do you wonder?"[1] to stimulate mathematical discussion. In moments of frustration or helplessness, fostering a growth mindset can empower students to view challenges as learning opportunities. Moving towards finding solutions, students can engage in mathematical calculations to determine quantities, such as the amount of water necessary for processing bamboo compared to cotton. This example showcases how mathematics can be utilized to deepen students' understanding of sustainability issues and encourages them to think critically about the environmental impact of their clothing choices.

In the context of exploring the impact of clothing choices on sustainability, students are exposed to valuable life lessons that intersect with mathematics. Analysing the linear relationship between water usage and cotton production gives rise to the application of linear equations, providing students with a mathematical framework to understand and quantify the environmental implications. Alongside this mathematical learning, students also navigate the emotional aspects of sustainability, fostering personal growth and resilience. Through critical thinking and logical reasoning, students can articulate convincing arguments using precise mathematical terms, such as why bamboo is a more water-efficient choice compared to cotton. This process empowers students to become leaders of change by exploring what actions they can take individually to contribute to a more sustainable future.

5. Conclusions

When implemented in the classroom, the utilization of our new model enriches mathematics lessons in various ways. By placing mathematics in the context of sustainability and employing mathematical tools in specific scenarios, students are exposed to a more meaningful and relevant learning experience. The incorporation of the mindset theory supports students in navigating their frustrations during mathematical tasks, fostering resilience and a growth mindset. Moreover, in the face of real-life challenges, such as climate change and pollution, mathematics and a growth mindset can provide students with the necessary tools and hope to understand and address these problems effectively. Overall, this model offers a powerful framework that promotes the integration of sustainability, mathematics, and mindset theory, empowering students to actively contribute to a more sustainable future.

---

1 Data talks by Youcubed provide guidance how to discuss graphs in the classroom; see https://www.youcubed.org/resource/data-talks/ and https://www.youcubed.org/resources/what-do-you-notice-what-do-you-wonder/.

Potential further work in this field includes reviewing the current use of sustainability in mathematics education, developing lesson plans and materials for integrating sustainability into mathematics, and exploring the application of sustainability to introduce concepts of pure mathematics. These endeavours will contribute to advancing growth-mindset mathematics education and deepening the understanding of sustainability within mathematical contexts.

References

Alpár, G., & van Hoeve, M. (2019). Towards growth-mindset mathematics teaching in the Netherlands. In *Proceedings of Learning Innova, 2* (pp. 1–17).

Boaler, J. (2015). *Mathematical mindsets: Unleashing students' potential through creative mathematics, inspiring messages and innovative teaching*. Jossey-Bass.

Dan, B. (2019). Neuroscience underlying rehabilitation: what is neuroplasticity? *Developmental Medicine & Child Neurology*, *61*(11), 1240–1240.

Dweck, C. (2017). *Mindset-updated edition: Changing the way you think to fulfil your potential*. Hachette UK.

Foster, C. (2013). Mathematical études: Embedding opportunities for developing procedural fluency within rich mathematical contexts. *International Journal of Mathematical Education in Science and Technology*, *44*(5), 765–774.

Hamilton, J., & Pfaff, T.J. (2014). Sustainability education: The what and how for mathematics. *Primus*, *24*(1), pp.61–80.

Gholami, K., Alikhani, M., & Tirri, K. (2022). Empirical model of teachers' neuroplasticity knowledge, mindset, and epistemological belief system. *Frontiers in Psychology*, *13*, 1042891.

IPCC (2022). *Summary for Ppolicymakers: Climate change 2022: Impacts, adaptation and vulnerability* (pp. 3–33). Cambridge University Press.

Kaplinsky, R. (2020). *Open Middle Math: Problems that unlock student thinking, Grades 6-12*. Stenhouse publishers.

Moreno-Pino, F.M., Jiménez-Fontana, R., Cardeñoso Domingo, J.M., & Azcárate Goded, P. (2021). Study of the presence of sustainability competencies in teacher training in mathematics education. *Sustainability*, *13*(10), 5629.

Phan, T.T., Do, T.T., Trinh, T.H., Tran, T., Duong, H.T., Trinh, T.P.T., Do, B.C., & Nguyen, T.T. (2022). A bibliometric review on Realistic Mathematics Education in Scopus database between 1972-2019. *European Journal of Educational Research*, *11*(2), 1133–1149.

Prieto-Saborit, J. A., Méndez-Alonso, D., Fernández-Viciana, A., Dixit, L. J. D., & Nistal-Hernández, P. (2022). Implementation of cooperative learning and its relationship with prior training of teachers, performance and equity in mathematics: A longitudinal study. *Sustainability*, *14*(23), 16243.

Sarrasin, J.B., Nenciovici, L., Foisy, L.M.B., Allaire-Duquette, G., Riopel, M., & Masson, S. (2018). Effects of teaching the concept of neuroplasticity to induce a growth mindset on motivation, achievement, and brain activity: A meta-analysis. *Trends in Neuroscience and Education*, *12*, 22–31.

Vorhölter, K., Greefrath, G., Borromeo Ferri, R., Leiß, D., & Schukajlow, S. (2019). Mathematical modelling. *Traditions in German-speaking Mathematics Education Research*, 91–114.

PATIS BIODIVERS: Engaging elementary students in authentic inquiry to improve the biodiversity of their schoolyard

Arnau Amat, Chadia Rammou

Grup de Recerca En Construcció de Coneixement,
Universitat de Vic – Universitat Central de Catalunya, Vic (Spain)

e-mail: arnau.amat@uvic.cat

1. Rationale of the project

After the United Nations Decade on Biodiversity (2011-2020), the Convention on Biological Diversity published a first draft framing the post-2020 Global Biodiversity Strategy. In the document, which is aligned with 2030 Sustainable Development Goal, set out a plan to implement numerous actions to bring about transformation in society's relationship with biodiversity (Convention on Biological Diversity, 2021).

Learning about biodiversity is seen as a key element of this strategy. According to Van Weelie and Wals (2002), there are four main arguments for working on biodiversity: a) emotional argument, based on personal meaning through discovery and experiencing biodiversity; b) ecological argument, based on understanding the global interconnections among the variety of elements of the ecosystem; c) ethical argument, based on dealing with values and taking a moral point of view in environmental issues; d) political argument, based on making choices and developing action competences.

Having said that, Gayford (2000) alerts that although there are numerous teachers who are concerned about biodiversity loss, they do no not know how to integrate this issue in their teaching lessons. The main obstacles are: a) the complexity of this issue, which requires an interdisciplinary approach; b) the constriction of time and the need to cover the science curriculum. Furthermore, it is important to remark how important curricular materials are to support teachers in these challenging obstacles. Regarding how to create an adequate TLS, several features should be considered. For instance, learning contexts – a specific setting where students learn, such as backyards and schoolyards – are revealed as an essential tool in making biodiversity meaningful for the students (Wals, 1999).

According to Afkin and Black (2003), authentic scientific inquiry means "doing of science" as the actual practice of scientific communities does. From a scientific authentic inquiry perspective, Roth and Lee (2004) also pointed out that goals in school science should be motivated by the same goals within the scientific or local community where the inquiry is taking place.

2. Overview of PATIS BIODIVERS project

PATIS BIODIVERS [BIODIVERSE SCHOOLYARDS] is a project with two major goals. On the one hand, to promote processes of authentic inquiry practices among kindergarten, elementary and secondary students, such as: collecting empirical data from their schoolyard, drawing conclusions, and promoting actions to improve the diversity of the species. On the other hand, to use this empirical data from schoolyards to do scientific research.

This project was born in November 2021 in Vic, a small city in a semirural area 70 km from Barcelona. The materials and the resources were created collaboratively by an interdisciplinary team of researchers from Universitat the Vic – Universitat Central de Catalunya (UVic-UCC), with the support of more than 40 teachers, from 13 different elementary and high schools of Vic. All these teachers participated in two different seminars to create two different kinds of materials.

First, teachers representing these schools participated in a seminar to design a methodology to implement a Bioblitz in the schoolyards. In the seminar, three sessions were dedicated to discussing how to organize the students, how to collect and register data and how to help students to identify the main species of the schoolyards. The challenge was to create a common methodology that was useful from kindergarten to secondary students. More than 800 students, from kindergarten to secondary students, participated in the school Bioblitz.

Second, 26 elementary and secondary teachers representing the schools participated in a second seminar with the main aim of create three Teaching and Learning Sequences (TLS) to work on the biodiversity of plants, invertebrates, and birds from an authentic inquiry point of view. First drafts of these TLS were created by the researchers from UVic – UCC and presented in the seminar. After the implementation of these TLS by teachers with their students, different focus groups were carried out to evaluate how the TLS worked, to improve the initials drafts. The three final TLS share the following structure in 3 phases:

- Contextualization phase: students become familiar with a real biodiversity issue and describe the main environments of their schoolyard.
- Inquiry phase: students collect real data of birds, plants or invertebrates in their schoolyard in order to find which environment has more biodiversity.
- Action phase: students have to think and design real actions to improve the biodiversity of plants, birds or invertebrates.

Currently, the project is open to every Catalan school interested in the project. The expectation is to have between 20 and 30 schools involved in the project at the beginning of next year. Now the materials are being translated in Spanish and Basque to expand the project geographically.

3. Overview to the research dimension of the project

Patis Biodivers is not just an innovative way of helping teachers to work on biodiversity in schools, but also is a good research context for understanding teaching and learning processes on Biodiversity. This communication attempt to reflect on how scientific inquiry and knowledge about biodiversity can be learned through a project like PATIS BIODIVERS. In particular, we are going to present two research goals:

a) To identify the main limitations and chances in working on biodiversity from teachers' views.
b) To evaluate the change in the students' ideas regarding the factors that promotes biodiversity and to identify he most meaningful moments in working on biodiversity from students' views.

For the purpose of this communication, only the research on the studies related to teachers' views is presented.

3.1 Researching on teachers' views

As presented above, the focus of this research goal is to identify the main purposes, limitations and chances perceived when working on biodiversity. In our view, understanding the main purposes of working on biodiversity could help us to select and adjust the main contents of future TLS, while knowing limitations and chances could also help us to design activity more adequate for teachers' needs.

In order to achieve this goal, in the first session of the course for the creation of the TLS, a questionnaire was distributed among the in-service teachers. In particular, in-service teachers were asked to name three main ideas and three main purposes when they work on a biodiversity project with their students. 10 questionnaires were analyzed for the purpose of the study.

Apart from that, notebooks were provided to the teachers involved in the project, to explain how each activity of the TLS was developed with their own primary and secondary students. Finally, interviews with the teachers who participated in the project were conducted to evaluate the project and to know their experiences while implementing the TLS with their students.

3.2 Preliminary results

From the questionnaires (Fig. 1), it could be seen how teachers identify that action to improve biodiversity is the most important learning goal when they work on biodiversity with students. They also identify the classification of groups of live beings, the work on habitat concept and the recognition of the main vegetal and animals species as important learning goals.

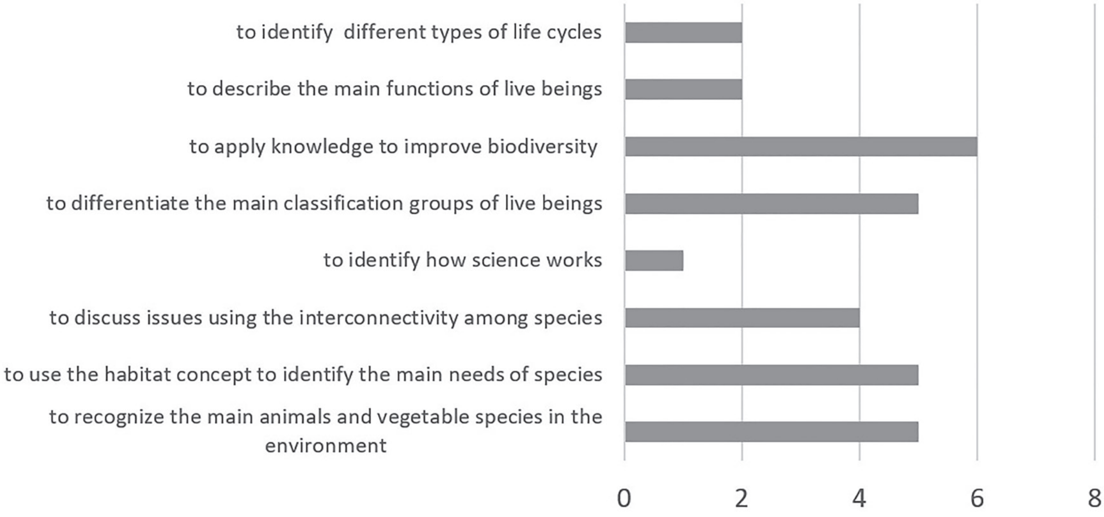


Figure 1. Main learning goals in a biodiversity project

Regarding the purpose, teachers justify the importance of working on biodiversity because students should understand the interconnectivity among species (Fig 2)

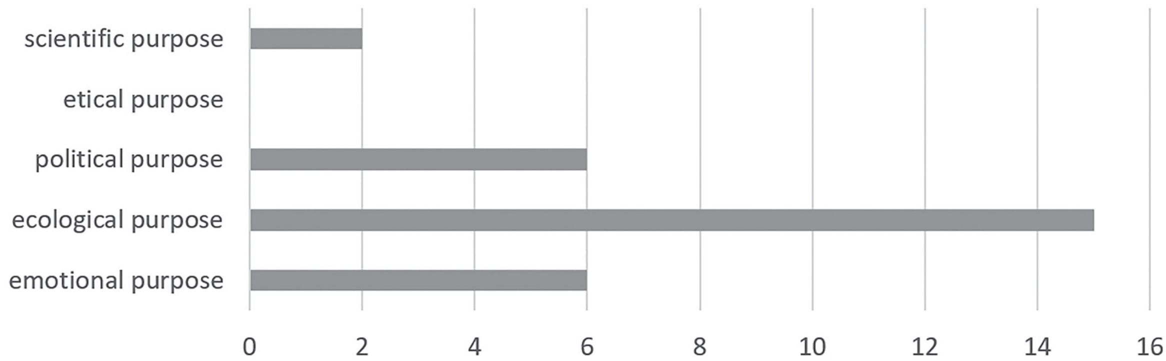


Figure 2. Main purposes to work in a biodiversity project (Based on arguments proposed by Van Weelie and Wals (2002))

From the notebooks and interviews, it could be seen how in-service teachers expressed in different moments difficulties in the identification of the most representative species. On the one hand, secondary teacher expressed the need to spend some time on working with the student in order to recognize the most representative species of the schoolyard. On the other hand, primary teachers express how difficult it was for themselves to recognize the species.

Furthermore, in-service teachers explained that the practice of analysing data from the species of the schoolyard is a time-consuming task. For this reason, some of them do analyze the data of the species that lived in the different environments of the schoolyard, in order to know how the biodiversity was distributed in the schoolyard.

Even though there are no literal excerpts regarding this topic, after analyzing what they did in the implementation of the TLS, primary and secondary students just had made decisions to improve the schoolyard, but none of these decisions were implemented.

3.3 Preliminary conclusions

From the preliminary results presented, it can be seen how, even though the most common learning goal of being involved in a biodiversity project is “to apply knowledge to improve biodiversity in the schoolyard” and “the political purpose” of acting to improve and take care of the environment, actually teachers had some difficulties to guide students to take tangible actions to improve biodiversity. In this respect, probably the “ecological purpose”, as an inner purpose of the participants, pushed teachers to do more activities to focus on the biological contents, such as: identification of species, working on the idea of habitat or ecosystems, and so on.

Having said that, obviously further research is needed. After opening the project to more schools and teachers, more data will be collected using the two tools presented in this paper: a modified questionnaire asking questions regarding learning goals, purposes, but also activities to achieve this goals.

Acknowledgements

This research was supported by Fundación Española para la Ciencia y Tecnología – Ministerio de Ciencia e Innovación

References

Afkin, J. M., & Black, P. (2003). *Inside science education reform: A history of curricular and policy change*. Teachers College Press.

Roth, W. M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education*, *88*(2), 263–291.

Gayford, C. (2000). Biodiversity education: A teacher’s perspective. *Environmental Education Research*, *6*(4), 347–361. doi: 10.1080/713664696.

Wals, A. (1999). *Environmental education and biodiversity*. National Reference Center for Nature Management.

Van Weelie, D., & Wals, A. (2002). Making biodiversity meaningful through environmental education. *International Journal of Science Education*, *24*(11), 1143–1156. doi: 10.1080/09500690210134839

Promoting teacher competencies towards sustainability conducted through STEAM interventions in IndagaSTEAM escuela project

Teresa Lupión-Cobos, Marta Alarcón-Orozco, Clotilde Lechuga-Jiménez

University of Malaga, Spain

e-mail: teluco@uma.es

1. School culture supporting STEM Education

Education improves constantly, so lifelong learning and continuing education/ professional development are a way of being updated on almost every innovative knowledge approach and learning strategy. STEM education contributes to scaffolding a holistic educational framework curriculum. In this line, to establish School Culture supporting STEM education is relevant to foster an education reform at all levels.

A place-based learning STEM approach in real-life contexts provides school subjects with meaningful elements either for teachers/professors or students. Furthermore, when implementing a constructivist teaching-learning approach, problem-based learning, and connections with real world items in the classroom, STEM approach is very efficient, especially using inquiry-based strategies. However, the STEM Education goal refers to a holistic integration of STEM areas across the curriculum, although it seems to lack specific scientific literature related to how the STEM acronym (and disciplines) should be implemented, because the whole is greater than the sum of its parts (Aguilera et al., 2021).

2. What is IndagaSTEAM Escuela Project

Professional development programmes can simultaneously explore mechanisms for integration across STEM and non-STEM disciplines, and help existing teachers develop a deeper understanding of the subjects they teach. (Margot & Kettler, 2019). They involve a shift from the teacher's role as a transmitter to a facilitator of knowledge, helping students to identify and use relevant sources to solve real-world problems. Sustained professional development programmes could have a positive impact on teacher teaching and student achievement. These programmes may also use a mentor or peer coach, allowing teachers to apply their learning in the classroom with the support of a peer coach. (Cotabish et al, 2013).

IndagaSTEAM Escuela Project is an experience to promote transfer of learning for students during their teacher training at schools - for compulsory education - to develop students' key competencies, conducted through cooperation between schools and universities by mentoring interventions (Lupión-Cobos et al., 2021).

Moreover, the following points are taken into account when designing the project programme: a) Teacher/Student centered approach, b) A curriculum reform, new organizational system and new teaching materials, c) HE & School projects implementing inquiry-based learning and place-based learning (Morrell et al., 2020; Author, 2021), d) Teaching and activities selection and design for Professionals and Students, and e) Activity impact evaluation in relation to the goal. In particular, several didactical aspects of the training process were addressed:

- Teaching as examining one's own practice in the classroom/reflecting as a professional: Teachers as managers of change and transformation in schools.
- The systemic nature associated with the change that it implies as an innovation in teaching practice requires consideration of different influencing elements (curriculum, school organisation, professional development or teaching materials, among others).
- School projects, using inquiry and contextualising strategies, have been identified as helpful training scenarios for applying STEM education objectives (Morrell et al., 2020; Author, 2021), which clarifies educational purposes and guidelines for its treatment.
- Activities to be used and how they fit in. The teaching skills to select and design them allow to formulate coherent and solid proposals with the intention of the proposed model. Its identification and design thus becomes a training objective that also articulates an expectation of professional practice.
- Systematically evaluate the impact of actions (interventions) and provide evidence/research evidence to guide improvement.

The program professional development of participants (teachers) is mainly focused on empowering and motivating learners to become active sustainability citizens, fostering critical thinking, and participating in shaping a sustainable future (Leal Filho et al., 2019). Thus, the project articulates teacher sustainability competences (Rieckmann, 2019). This proposal describes teacher sustainability competences through a project design and its implementation to stablish relations between them: a) PBL STEAM "How can I improve my environment" (Topic 2 "material") and b) sustainability competences by the teacher (Topic 1 "personal").

3. PBL STEAM "How can I improve my environment" for teaching competences associated to Agenda 2030

The school project was designed and implemented in primary schools (6-12 years old children) by primary school teachers during the 2020-2021; 2021-2022 course. It was developed in 6 weeks (from the second half of April to May), divided in three phases (1 = Initial, 2 = Development and 3 = Final) which includes 7 work sessions with activities for students who were working in a Class Group (CG) and in Small Groups (SG).

In phase 2, the teacher helps pupils to develop their understanding of the world as an interconnected whole, to look for connections in the social and natural environment, and to consider the consequences of their actions, by visiting a natural environment located close to the school. Its design is planned as a work project tackled from a transdisciplinary approach, with STEAM areas being its backbone.

In every session, collecting data tools are used to evaluate results (which are likely to be used either for students or the project).

The initial phase starts with a CG kickoff workshop introducing the topic environmental awareness & sensibilization and reflect about 2030 Agenda for Sustainable Development Goals (SDGs), enabling students to focus the problem to be addressed (environmental pollution), using thinking techniques (Word-Idea-Phrase). Activities design and implementation allow teachers to initiate a wide range of competencies related to sustainability in each phase of the project, which are categorized according to Rieckmann's description (2019) (Figure 1).

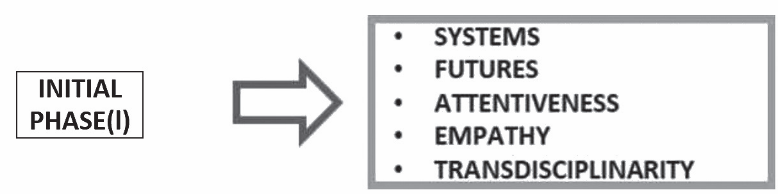


Figure 1. Sustainability competences for teachers expressed in phase 1 of the project

Phase 2 & 3 foster the sense of understanding our interconnected world (with teacher support), searching links among social and natural areas, bearing in mind how the consequences of one action's would affect the environment. Furthermore, a nearby natural site is chosen for a scholar visit which needs a former inquiry. Students (CG) search for information and draft an "Environmental Eco-audit" which allows them to know and contrast "in situ" the environmental location and its characteristics. Moreover, students are asked to explore future alternatives and use them to deliberate about how they might change their behaviors to support sustainable development, driving their work to elaborate an "Eco-Tourist Guide", to design "Informative- persuasive signage to promote good habits", and a proposal at the school for "Creation of vertical gardens with native aromatic plants". In addition, critical thinking related to non-sustainability actions are launch by the teacher fostering sustainable awareness and the need of a societal change, from a receptive and inclusive perspective, reinforcing their sustainable believes and values. In Phase 3, SG presents their final work to CG in oral presentations using murals, posters and/or digital resources.

The whole project implements transdisciplinary lines, especially using STEAM as the main axis, fostering creativity and proactive decision making, to strengthen students to critically evaluate the reliability of environmental management models, accepting responsibility for their work acting prudently and timely.

Sustainable competences for teachers described by Rieckmann (2019) are always borne in mind (Figure 2).

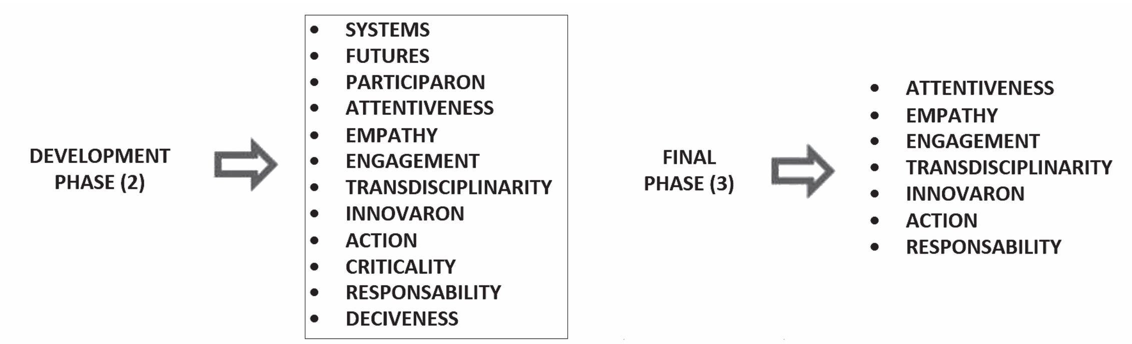


Figure 2. Sustainability competences for teachers expressed in phases 2 &3 of the project.

Acknowledgements

This work is being carried out within the context of the following projects: I+D+i PID2019- 105765GA-I00 «Ciudadanos con pensamiento crítico: Un desafío para el profesorado en la enseñanza de las ciencias», MCIN/AEI/10.13039/501100011033, funded by the Spanish Government (2020-2023); Educational Innovation Project PIE22-115 «Uso de prácticas científicas en proyectos STEAM. Acercamiento en estudiantes universitarios desde las competencias profesionales» (2023-2024), funded by the University of Malaga (Spain); European project "Exploring European Cultural Heritage for fostering academic teaching and social responsibility in Higher Education (EUCUL)" (2018-2021), KA-203051104, funded by the European Union.

The study was conducted in accordance with the protocol approved by the Ethical Committee of Experimentation of the University of Malaga (CEUMA) reference 31-2022-H.

References

Aguilera, D., Lupiáñez, J.L., Vílchez-González, J.M., & Perales-Palacios, F.J. (2021). In search of a long-awaited consensus on disciplinary integration in STEM education. *Mathematics*, *9*, 597. https://doi.org/10.3390/math9060597.

Cotabish, A., Dailey, D., Robinson, A., & Hughes, G. (2013). The effects of a STEM intervention on elementary students' science knowledge and skills. *School Science and Mathematics*, *113*(5), 215–226.

Lupión Cobos, T., Valencia Ruiz, J., & Crespo Gómez, J.I. (2021). Estudio de una experiencia de indagación escolar en Ed. Primaria a través del Proyecto IndagaSTEAM Escuela. Valoraciones docentes de su transferencia a la práctica". In *Actas electrónicas del XI Congreso Internacional en Investigación en Didáctica de las Ciencias 2021. Aportaciones de la educación científica para un mundo sostenible*, (pp. 2133–2136). Enseñanza de las Ciencias.

Margot, K., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*(2), 1–16 https://doi.org/10.1186/s40594-018-0151-2.

Morrell, P. D., Park Rogers, M. A., Pyle, E. J., Roehrig, G., & Veal, W. R. (2020). Preparing teachers of science for 2020 and beyond: highlighting changes to the NSTA/ASTE standards for science teacher preparation". *Journal of Science Teacher Education*, *31*(1), 1–7.

Rieckmann, M. (2019). Education for sustainable development competencies for educators. https://www.researchgate.net/profile/Marco_Rieckmann/publication/337440344_Education_for_Sustainable_Development_Competencies_for_Educators/links/5dd7af64299bf10c5a26db8a/Education-for-Sustainable-Development-Competencies-for-Educators.pdf

Roles, practices and competencies of STEM-teacher educators

Sarah-Maria Rotschnig, Stefan Zehetmeier

Institute of Instructional and School Development, University of Klagenfurt

e-mail: Sarah-Maria.Rotschnig@aau.at

Abstract

This paper looks at the different roles of teacher educators, their competencies, and professional practices. To gain an insight into the current state of research on this topic, a theoretical input will be given at the beginning. Building on this, there will be a discussion of relevant issues in the context of teacher educators' professionalisation, to capture different country perspectives and to foster networking concerning this topic.

Keywords

professional roles, practices, competencies, teacher education, STEM roles, practices and competencies of STEM-teacher educators

1. Relevance of the topic concerning the overall conference theme

The focus of the conference is on Educating the Educators. This theme includes professionalisation aspects that relate to different dimensions. On the one hand, current research in this area focuses on the roles of teacher educators; on the other hand, questions about the quality of professional development approaches and also the professional identity of teacher educators are in the spotlight.

A lot is already known about the design criteria for effective teacher education (Lipowsky & Rzejak,2021). Comparatively less is known about the competencies and practices of teacher educators. The demands in this professional field are high, which makes it worthwhile to take a closer look at how teacher educators act.

In particular, we refer to the following question "Which roles and ways of working have to be considered in the professional development courses for PD course leaders and facilitators in professional learning?" (Call for Papers, p. 3)

2. Content in a nutshell

"Teacher educators are all those who actively facilitate the (formal) learning of student teachers and teachers", states an article by the European Commission (2013, p. 8). This quote makes clear that teacher educators are active in both initial and in-service teacher education and play essential roles in this regard (European Commission, 2013).

Teacher educators have a central function in the educational system which, despite its importance, has long been neglected by scholars. Some authors, therefore, refer to this profession as a “hidden profession” (Livingston, 2014; Meeus et al.,2018).

In the last 30 years, international research has begun to focus increasingly on teacher educators. The term “teacher educator” encompasses an extremely heterogeneous professional group : Teacher educators can be university lecturers, researchers, school teachers, mentors, supervisors, and school administrators (Schrittesser, 2020).

A relevant reference point in this field is the literature review by Lunenberg and colleagues (2014). The authors shed light on the professional actions of teacher educators in different roles. In particular, they emphasize: “Hence, if we wish to take the profession of teacher educator seriously, this situation asks for a solid analysis and synthesis of what is known in this field”. (Lunenberg et al., 2014, p. 1)

Lunenberg and colleagues capture the knowledge and skills of teacher educators in six different roles: “teacher of teachers”, “researcher”, “coach”, “curriculum developer”, “gatekeeper”, and “broker” (Lunenberg et al., 2014). Each role emphasizes a different focus in the work of a teacher educator and is associated with differentiated tasks, demands, and actions.

Our contribution will focus on the role “teacher of teachers”.

Essential for this role are the corresponding subject-specific, subject-didactic, and pedagogical expertise (Shulman, 1986) in this field of action.

The role “teacher of teachers” is central not only to preparing teaching content in an appealing way but also to expressing principles and theories based on it (Lunenberg et al., 2014). For example, knowledge about adult-oriented teaching and learning settings , self-regulated learning, or dealing with various challenges that may arise during work.

Professionalism of teacher educators in this specific role is particularly evident through “second order teaching” (Lunenberg et al., 2014). So-called “first order teaching” is content-related and answers the question of what is being taught. Second order teaching, on the other hand, addresses the context of teaching and learning with the question of how teaching is done (Balsby Thingholm & Bering Keiding, 2018). Learning should be explicated as a separate dimension, for example, to make theories of self-regulated learning conscious and applicable.

The professionalism of teacher educators is different from that of teachers in schools. In recent years, governments’ attention has focused on teacher educators as a professional group because they play an essential role in the quality of teacher learning (European Commission, 2013).

Looking more closely at professionalism, there is an opportunity to define it through common standards and thus create common guidelines. From a theoretical viewpoint, this perspective represents “demanded professionalism” (Vanassche, 2022). It involves prescriptive assumptions and a “blueprint approach”. In contrast, there is a perspective that looks at professionalism from the point of practice. This is called “enacted professionalism” (Vanassche, 2022). In this context, the “International Forum for Teacher Educator Development” (InFoTED) has developed a conceptual model described by Vanassche and colleagues (2021, p. 18) as follows:

“That is, we aim to present a model to conceptualise, study, and actively support teacher educator development, which takes as its central unit of analysis not the “mental sediment” of individual teacher educators’ professionalism (i.e., knowledge, cognition, competence, etc.), but the actual enactment of their professionalism in teacher education practices and all the complexities these entail.”

With this approach, the authors attribute to teacher educators that they always have good reasons for their concrete actions and enact their expertise in practice (Vanassche et al., 2021).

In this context, a research gap is identified, which we want to address and discuss to “map the terrain” and to obtain diverse perspectives on it:

“The work as a teacher educator requires a variety of competencies, such as subject knowledge, subject didactic and pedagogical competencies, or counselling competencies. The higher education didactic and adult education skills of teacher educators must be systematically enhanced. Research on and evaluation of competencies and practices of teacher educators in pre-service education as well as in continuing education are a valuable research desideratum, especially in connection with the impact and transfer [...]” (Müller et al., 2019, pp. 131f.)

References

Balsby Thingholm, H. & Bering Keiding, T., (2018). Second order teaching. *International Society for Teacher Education*, *22*(1), 56–64.

European Commission (2013). *Supporting teacher educators for better learning outcomes*.

Livingston, K. (2014). Teacher educators: hidden professionals? *European Journal of Education*, *49*, 218–232.

Lipowsky, F. & Rzejak, D. (2021). *Making in-service training effective for teachers*. https://doi.org/10.11586/2020080

Lunenberg, M., Dengerink, J., & Korthagen, F. (2014). *The professional teacher educator: Roles, behaviour, and professional development of teacher educators*. Sense Publishers.

Meeus, W., Cools, W., & Placklé, I. (2018). Teacher educators developing professional roles: Frictions between current and optimal practices. *European Journal of Teacher Education*, *41*, 15–31.

Müller, F. H., Kemethofer, D., Andreitz, I., Nachbaur, G., & Soukup-Altrichter, K. (2019) In-service and further teacher education. In S. Breit, F. Eder, K. Krainer, C. Schreiner, A. Seel, & C. Spiel (Eds.), *Nationaler Bildungsbericht Österreich 2018, Band 2: Fokussierte Analysen und Zukunftsperspektiven für das Bildungswesen* (pp. 99–142). Federal Institute for Quality Assurance of the Austrian School System (IQS).

Schrittesser, I. (2020). Qualification paths of lecturers in teacher education. In C. Cramer, J. König, M. Rothland, & S. Blömeke (Eds.), *Handbook Teacher Education* (pp. 843–850). Verlag Julius Klinkhardt.

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, *15*, 4–14.

Vanassche, E., Kelchtermans, G., Vanderlinde, R., & Smith, K. (2021). A conceptual model of teacher educator development: An agenda for future research and practice. In R. Vanderlinde, K. Smith, J. Murray, & M. Lunenberg (Eds.), *Routledge research in teacher education. Teacher educators and their professional development: Learning from the past, looking to the future* (pp. 15–27). Routledge.

Vanassche, E. (2022). Four propositions on how to conceptualize, research, and develop teacher educator professionalism. *Front. Educ., 7*, 1036949. doi: 10.3389/feduc.2022.1036949

Subject matter didactics for connections between the components of STEM

Hannes Stoppel

Paderborn University, Germany

e-mail: stpl@max-planck-ge.de

Abstract

The parts of STEM stand in relationship with each other and are connected with each other. To enable students to apply mathematics in science, technology, and engineering, teachers need to anticipate and understand students' difficulties and if necessary to simplify mathematics for the application by students. Teachers need to know and to understand the mathematical background and be able see the connections of the topics of STEM with each other. By the results of the study, subject matter didactics in connection with activity theory according to Engeström is a support for the development of STEM research or in the development of STEM material for lessons.

Keywords

subject matter didactics, activity theory, mathematics as glue of STEM components

Introduction

Undoubtedly, the parts of STEM are closely connected to each other. To enable students to apply mathematics in STE, teachers need to anticipate and understand students' difficulties and, if necessary, to simplify mathematics for the application purposes. Therefore, teachers need to know and understand mathematical backgrounds and recognize the connections of the topics of STEM with each other. To impart mathematical background, didactical considerations are necessary, and this leads to subject matter didactics (SMD, German "Stoffdidaktik", f. e. Straesser 2014). What is more, Nobel prize winner Roger Penrose noticed that "the mathematics which seems to be in control of our physical world is exceptionally fruitful and powerful, simply as mathematics" (Penrose 1997, p. 95). Mathematics seems to be understood as the glue between STEM components (Livstrom et al., 2019), see Figure 1, left.

In this paper, we will examine the significance of SMD for teachers by considering some examples of STEM teaching sequences. The aim of the study is to consider the following questions: (1) How can we characterize the application of SMD for the design of STEM teaching sequences? (2) In how far does SMD help to build and understand the connections between the components of STEM? (3) To what depth do teachers need scientific background, in relation to the lessons they intend to teach?

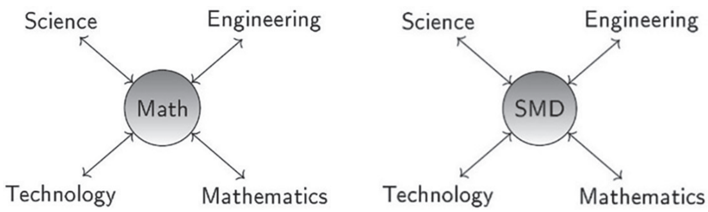


Figure 1. Mathematics as the glue between STEM components (left), SMD as the connection between STEM components (right)

2 Theory

2.1 STEM and education

Livstrom et al. (2019) define the STEM approach as interdisciplinary for learning various scientific concepts combined or associated with real-world events. In modelling contexts, they perceive mathematics as the glue between STEM components. Ideally, teachers can select from a variety of learning models in order to support their students' learning, in the sense of making it easier and more effective for them to comprehend and master the necessary skills (Cheng & So, 2020). According to Hobbs et al. (2018), STEM is not only a combination of different disciplines, but "what is needed is a vision that is inclusive and interdisciplinary in nature and specific to school needs" (p. 134). Their reflections lead to the different models of STEM teaching shown in Figure 2. In models 1 and 2, the disciplines are separate, and teachers only need competences in one STEM component. In the other models, teachers need competences to connect and combine the different STEM components.

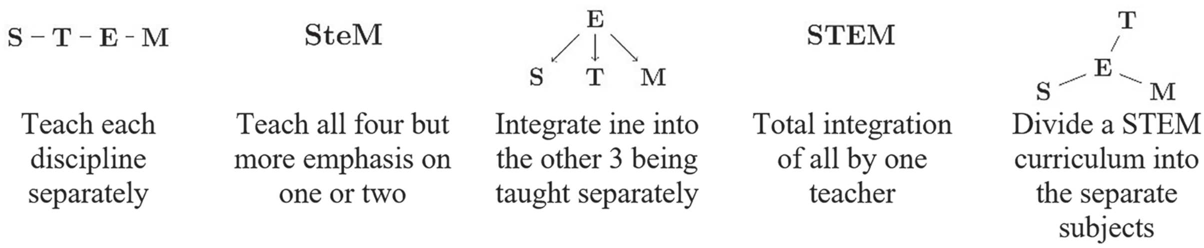


Figure 2. Models of STEM teaching in schools (according to Hobbs et al., 2018, p. 144)

2.2 Subject Matter Didactics

Teachers need knowledge and understanding of mathematical backgrounds of the contents of their lessons (Hefendehl-Hebeker, 2022). In order to teach competently, they need subject matter didactics (SMD), too. Hefendehl-Hebeker (2022) defined SMD as the part of mathematics education with expert knowledge as foundation and environment for the teaching of mathematics. To be able to utilize SMD appropriately, teachers need knowledge and understanding of mathematical background (Stoppel, 2021). The vast majority of scientists and mathematics educators regard SMD as fundamental for the education of mathematics teachers (e. g., Ball et al., 2008). The notion of SMD also applies to STEM components like abstract mathematics (Loos, Sinn & Ziegler, 2022), chemistry or biology (Nerdel, 2017), physics (Halloun, 2006) and computer science (Modrow & Strecker, 2016). According to Beswick and Fraser (2019), who point out the importance of mathematics, SMD should not be reduced to single elements of STEM, but should be regarded comprehensively, resulting in a need of SMD for STEM teachers. It means that one should not regard mathematics, but SMD as the glue between the STEM components, see figure 1, right.

2.3 Activity Theory

Cognitive processes can be examined with the psychology of aging to describe the conditions of individual and social life. Activity Theory (AT), that "is the common lens that guides the analysis across multidisciplinary fields" (Núñez, 2009, p. 8). It can be described as a "psychological and multidisciplinary theory with a naturalistic emphasis that offers a framework for describing activity and provides a set of perspectives on practice that interlink individual and social levels" (Barab et al., 2004, p. 199). Leontiev (1978) and Engeström (1987) introduced significant frameworks for AT. Leontiev describes individual activities, whereas Engeström describes collective actions in his framework as an object-oriented, collective, and culturally mediated human activity, as illustrated in Figure 3. The subject component is defined as an individual or individuals, the object refers to the immediate goals of the activity. Tools are "anything used in the transformation process, including both material tools and tools for thinking" (Kuutti, 1996, p. 14). The community consists of people and groups whose knowledge, interest, states, and goals shape the activity, and rules represent norms, conventions or social traditions. How the work in the activity is divided among participants is referred to by the division of labor.

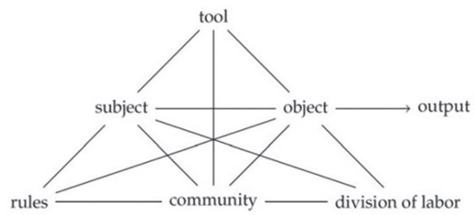


Figure 3. Model of an activity system from Engeström (1987)

3 Design of the study

3.1 Structure of courses

For the study we chose different courses of Grade 9 to 12 at a German high school and in extracurricular academies for gifted students of Grade 12. We planned, taught, and analysed sequences of lessons. Two topics addressed in the courses were (1) Chaotic Dynamical Systems and (2) Quantum Computers (QC), using postgraduate literature. The choice of topics was influenced by different STEM elements. Topic (1) includes nonlinear dynamics for systems over R and C up to the Mandelbrot set. The central component is mathematics, with connections to computer science. Topic (2) deals with mathematics, technology, computer science, and physics; we chose the IBM Quantum Experience.

3.2 Data collection and evaluation

According to Hobbs et al. (2018), there are several models for teaching STEM in schools (Figure 2). There can be more emphasis on one or two components (model 2), or one component is integrated into the other three (model 3), thus revealing connections between the STEM elements. We will analyse these connections in relationship to SMD via AT.

For the application of AT to SMD we interpret the components of the learning activity as shown in Table 1. Instead of interpreting the individual as subject, we specify the object in connection with the contents of the courses and their products (in the form of students' reports). Therefore, rules, division of labor, and objects should also be understood in connection with students' report. Here, the tools are taken as teachers' SMD, and the community is understood as an activity from teachers towards students (Figure 4).

Table 1. Learning activities in connection with SMD (*teacher's activity*, **students' activity**)

Subject	**students' ambition, formulate questions for teachers**
Tools	*subject matter didactics*
Rules	*students' scientific knowledge, search for working material*
Community	*imparting to students*
Division of labor	**presentation of solution process and interim results to students**
Object	**students' solutions and competences**

SMD is understood as a tool of a learning activity. As described in section 2.2, SMD is important in connection with scientific backgrounds. It builds the foundation for the teachers' ability to support students in the application of mathematics in their projects. Without SMD, teachers might be unable to sufficiently support students in their projects, for example to help them find a suitable topic for their project, reduce background complexity appropriately, and support them by finding apposite literature. During the project work teachers can help students to present interim results to the other members of the course.

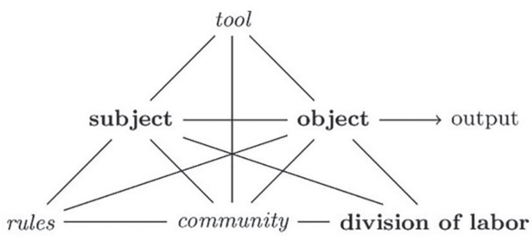


Figure 4. Model of AT in connection with SMD (teacher's activity, students' activity)

Contents of the courses for teachers and students

In the course on Chaotic Dynamical Systems, the structure of the Mandelbrot Set $\mathcal{M}$ and Julia Sets J_c with c∈ℂ were examined. From a topological perspective, we have the astonishing result that J_c is either connected or a Cantor set, but never anything in between. Actually, $\mathcal{M}$={c∈ℂ: J_c is connected}, and J_c is a Cantor set, iff c∈$\mathcal{M}$. The teacher needs background knowledge in topology and must be able to reduce this knowledge for application by students, e. g. via graphs of J_c and $\mathcal{M}$ subject to *c* by means of a computer algebra system. For students, teachers need to reduce the contents, e.g., to graphical presentation as shown in Figure 5. The connectedness and disconnectedness of different J_c is visible, but one cannot deduce that J_c is a Cantor set iff c∈$\mathcal{M}$. Teachers need SMD to let students understand what this means. They should have a background in several parts of mathematics such as complex analysis and topology.

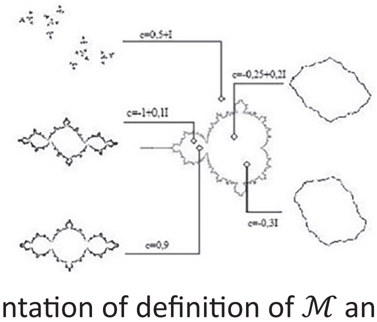


Figure 5. Graphical presentation of definition of $\mathcal{M}$ and J_c is a Cantor set, iff c∈$\mathcal{M}$

A suitable goal for students is the application of a quantum computer in the context of computer science. Operations with Qubits $\alpha|0\rangle+\beta|1\rangle$ are described with the states $|0\rangle,|1\rangle$, $\alpha,\beta\in\mathbb{C}$ and $|\alpha^2+\beta^2| = 1$. These become visible with the Bloch sphere shown on the website. Transformations of quantum waves can be described with $|\psi\rangle=\cos(\theta/2)\ |0\rangle+ e^{i\phi}\ \sin(\theta/2)\ |1\rangle$. Quantum gates, which are given, e.g., by Pauli-matrices like $Y=\begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$, are depicted by special symbols. Operations of the matrices are performed via the tensor product. Here, teachers need background knowledge about C and linear algebra, whereas students can manage with elementarizations for their projects.

Teachers should have a backgrounds in several part of mathematics as linear algebra, complex analysis and vector calculus, and be able to reduce it as far as necessary for students, e. g. by referring to quantum computers used the IBM Quantum Experience, https://quantum-computing.ibm.com/ (Figure 6).

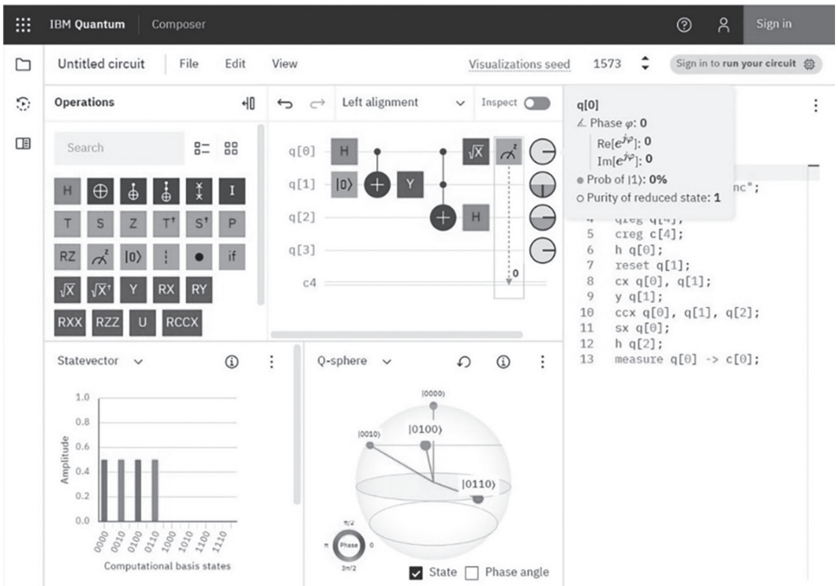


Figure 6. IBM Quantum composer

We described the two levels of students and teachers. Ideally, teachers should be familiar with all components of SMD shown in Table 1 in order to decide about possibilities and ways to address these topics in their courses and adapt them individually for their students.

Conclusions

As our elaborations show, AT helps to realise and understand the structure of projects reports. In particular, it shows the importance of teachers' competences for the design of projects for students, and for watching, noticing, and supporting students when working on their projects. AT is eligible for teachers to plan and to evaluate lectures. Clearly, teachers need SMD to fulfil these tasks. This gives an answer to research question (2).

The description of the courses yields answers to research questions (1) and (3). It becomes obvious that background knowledge of the topics is indispensable for teachers. Teachers need deep background knowledge to overview possible goals, difficulties, knowledge necessary to comprehend descriptions of topics, and their foundations in application and/or theory.

In sum, we can say that teachers need a stable background in SMD in order to provide students with the learning opportunities offered by complex STEM topics. For further research objectives, we recommend to extend the study by examining the learning processes of individual students, in order to gain insight into how to apply SMD to optimise the learning experience for students.

References

Ball, D., Thomas, M., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389–407.

Barab, S. Q., Evans, M. A., & Baek, E-O (2018). Activity theory as a lens for characterizing the participatory unit. In R. Jorgensen & K. Larkin (Eds.), *STEM Education in the Junior Secondary. The State of Play*. Springer Singapore.

Beswick, K. & Fraser, S. (2019). Developing mathematics teachers' 21st century competence for teaching in STEM contexts. *ZDM*, *51*(6), 955–965.

Cheng, Y. C., & So, W. W. M. (2020). Managing STEM learning: A typology and four models of integration. *International Journal of Educational Management*, *34*(6), 1063–1078.

Engeström, Y. (1987). *Learning by expanding. An activity theoretical approach to developmental research*. Orienta-Konsultit.

Ernst, F. & Schweikard, A. (2020). *Fundamentals of machine learning. Upport vector machines made easy*. UVK Verlag.

Halloun, I. A. (2004). *Modeling theory in science education*. Kluwer Academic Publishers.

Hefendehl-Hebeker, L. (2022). *Was ist und was soll die „Stoffdidaktik"?* Opening presentation of KIT-Workshop „Einblicke in die moderne Stoffdidaktik", Karlsruhe. Available from: https://www.math.kit.edu/didaktik/seite/stoffdidaktik/media/22_kit-didaktik-ws_hefendehl-hebeker_va.pdf

Hobbs, L., Clark, J. C. & Plant, B. (2018). Successful students – STEM program. Teacher learning through a multifaceted vision for STEM education. In R. Jorgensen & K. Larkin (Eds.), *STEM Education in the Junior Secondary. The State of Play*, *(*pp. 133–168). Springer Singapore.

Kuutti, K. (1996). Activity theory as a potential framework for human-computer interaction research. In B. A. Nardi (Ed.), *Context and consciousness. Activity theory and human-computer interaction*, (pp. 17–44). The MIT Press.

Leontiev, A. (1978). *Activity, consciousness, and personality*. Prentice-Hall.

Livstrom, I. C., Szostkowski, A. H., & Roehrig, G.H. (2019). Integrated STEM in practice. Learning from Montessori philosophies and practices. *School Science and Mathematics*, *119*(4), 190–202.

Loos, A., Sinn, R., & Ziegler, G. M. (2022). *Panorama der Mathematik*. Springer.

Modrow, E. & Strecker, K. (2016). *Didaktik der Informatik*. De Gruyter Oldenbourg.

Nerdel, C. (2017). Grundlagen der Naturwissenschaftsdidaktik. Kompetenzorientiert und aufgabenbasiert für Schule und Hochschule. Springer Spektrum.

Núñez, I. (2009). Activity theory and the utilisation of the activity system according to the mathematics educational community. *Educate*, *Special Issue*, 7–20.

Penrose, R. (1997). *The large, the small and the human mind*. Cambridge University Press.

Stamoulis, E. & Platitsi, K. (2012). Activity theory, history and philosophy of science, and ICT technologies in science teaching applications. In K. Plakitsi (Ed.), *Activity theory in formal and informal science education*, (pp. 111–157). Sense Publishers.

Straesser, R. (2014). Stoffdidaktik in Mathematics Education. In S. Lerman (Ed.), *Encyclopaedia of Mathematics Education*, (p. 567). Springer.

Stoppel, H. (2021). Making particle physics and cosmology accessible for high school students. In DESY (Ed.), *37th International Cosmic Ray Conference ICRC 2021*, Processing of Science, Trieste. Available from https://pos.sissa.it/395/1369/pdf [28. February 2023].

Sustainability-related personal values of pre-service biology teachers

Virginia Deborah Elaine Welter, Moritz Krell

IPN – Leibniz Institute for Science and Mathematics Education, Kiel, Germany

e-mail: vdewelter@gmx.de

Abstract

Educators can have a great impact as role models, particularly at the level of attitude formation. This is all the more important because attitudes toward complex issues such as sustainability are less rigid and therefore easier to change. Thus, teachers' broader personal value sets can play a critical role in the successful implementation of UNESCO's Education for Sustainable Development goals in their classrooms. Our study shows that while university teacher training in biology seems to be significantly positively associated with the development of the nature-based universalism value, other sustainability-related values do not change in a similar way, although teacher training offers great potential in this regard.

Keywords

sustainability, values, attitude formation, role model, university teacher education, (pre-service) biology teachers

1. Relevance of Teachers' Personal Values

The likelihood that teachers will be able to successfully implement Education for Sustainable Development (ESD; UNESCO, 2017) in their everyday teaching largely depends on their professional competence (Dunn & Hattie, 2022). However, the broader set of personal values teachers hold may also play a crucial role in successfully adapting ESD to their classroom (Corrigan et al., 2020). Values are cross-situational goals that guide individuals or social groups and vary in importance (Schwartz et al., 2012). If a value, such as sustainability, is of particular importance to a person, he or she is more likely to choose those attitudes and behaviors that correspond to that value (Rokeach, 1973).

Several authors have already argued that and how teachers' personal values may affect their teaching (e.g., Simon & Connolly, 2020). A study by Harland and Kinder (1997) showed that a perceived mismatch between teachers' personal values and those embedded in the curriculum decreases the likelihood of implementing specific instructional approaches and taking adequate time to teach relevant topics. However, teachers' values are important for a second reason: According to the socio-emotional domain of ESD (UNESCO, 2017), the acquisition of values conducive to sustainability is explicitly mentioned as a learning goal. Indeed, values develop and change through learning experiences, the environment, and ongoing adaptation to new situations and lifestyles (Rokeach, 1973).

It is therefore important to take a closer look at teachers' sustainability-related personal values in order to evaluate whether these are congruent with ESD or whether specific learning opportunities are needed to specifically change any value discrepancies that may exist.

2. Research Questions

1) Does a sample of pre-service biology teachers (PBTs) show higher levels of sustainability-related values than a reference sample (71% university students of different majors; 29% adults) that was surveyed 10 years ago?

2) Is there a positive association between the number of ESD-related learning opportunities in biology teacher education (operationalized by semesters of study completed) and the level of sustainability-related values, even after partialling out the influence of the PBTs' age?

3. Methods

We conducted a cross-sectional survey including $N = 151$ PBTs from a university in Germany. We specifically selected this group as ESD in German curricula is mainly covered by the subject of biology.

The operationalization of sustainability-related values was based on Schwartz et al.'s (2012) refined theory of basic values, which covers 19 discriminable values that can be assessed using the Portrait Value Questionnaire – Revised (PVQ-R). A closer look at the PVQ-R reveals that the three universalism values covered are almost congruent with the key ESD goals: (1) *Concern*: Commitment to equality, justice, and protection for all people; (2) *Nature*: Preservation of the natural environment; (3) *Tolerance*: Acceptance and understanding of those who are different from oneself.

We asked our participants to answer the universalism-related PVQ-R items (three items per value; scale range from 1 [min] to 6 [max]) as well as sociodemographic questions to assess their age and semester of study.

Research question (RQ) 1 was answered by comparing our sample to the PVQ-R norm sample that was surveyed by Schwartz et al. in 2012. We calculated Hedges' g, which accounts for different sample sizes and can be interpreted analogously to Cohen's d. RQ2 was answered by calculating partial correlations.

4. Results

Regarding RQ1, our results show that, compared to the reference sample, our sample of PBTs shows higher levels of all three universalism values (medium effect sizes; Table 1).

Table 1. Differences in universalism values between a reference sample (Schwartz et al., 2012) and our sample

Universalism value	Reference sample (N = 3,261)		Analysis sample (N = 151)		g_{Hedges}
	M	*SD*	*M*	*SD*	
Concern	4.72	0.78	5.25	0.70	0.68
Nature	4.02	0.87	4.65	1.06	0.72
Tolerance	4.61	0.71	5.10	0.65	0.69

Regarding RQ2, we found a low, but significantly positive partial correlation ($r = .16$, $p < .05$) between semesters of study and the level of the nature-related universalism value. With respect to concern- and tolerance-related values, however, there were no significant correlations.

5. Discussion

Overall, our results show both positive aspects and possible starting points for action. Regarding RQ1, we cannot be sure whether the higher scores of our sample of PBTs are a result (a) of a general trend over time or (b) of the fact that their major is biology or (c) of a mixture of both. However, considering the fact that the maximum PVQ-R scale value is 6, we still interpret the result favorably. A clearer need for optimization is revealed by the correlational results. Despite the fact that university teacher training in biology seems to be significantly positively associated with the development of the nature-related universalism value, other sustainability-related values do not seem to change in a similar way, although teacher education offers a lot of potential in this respect.

Empirically, it has been shown that university students' intention to engage in sustainable behaviors considerably depends on what they perceive to be the social norm. In this respect, university professors, CEOs, and politicians are seen as most important benchmarks regarding sustainable behavior (Swaim et al., 2014). Thus, particularly at the level of attitude formation, educators can have a great impact as role models. And this is even more important because attitudes toward complex issues like sustainability are less fixed and therefore easier to modify (Linville & Jones, 1980).

In order to effectively promote the acquisition of values conducive to sustainability among pre-service teachers, it may be beneficial for professors involved in university teacher education to consistently bring up their own sustainability-related values (e.g., in brief anecdotes) and, of course, to behave accordingly (e.g., ride a bicycle to work). In addition, community-based learning should not be forgotten in university teacher education, as it has been shown to encourage reflection on one's own civic responsibility (Ibrahim, 2010).

References

Corrigan, D., Buntting, C., Jones, A., & Fitzgerald, A. (2020). The shifting sands of values in science education. In C. Corrigan, A. Buntting, A. Fitzgerald, & D. Jones (Eds.), *Values in Science Education*, *Vol. 1* (pp. 1–4). Springer.

Dunn R., & Hattie, J. (2022). *Developing teaching expertise*. Corwin.

Harland J., & Kinder, K. (1997). Teachers' continuing professional development. *J In-Serv Educ*, *23*, 71–84.

Ibrahim, M. (2010). The use of community based learning in educating college students in Midwestern USA. *Procedia Soc Behav Sci*, *2*, 392–396.

Linville, P. W., & Jones, E. E. (1980). Polarized appraisals of outgroup members. *J Pers Soc Psychol*, *38*, 689–703.

Rokeach, M. (1973). *The nature of human values*. The Free Press.

Schwartz S.H., Cieciuch, J., Vecchione, M., Davidov, E., Fischer, R., Beierlein, C., Ramos, A., Verkasalo, M., Lönnqvist, J.-E., Demirutku, K., Dirilen-Gumus, O., & Konty, M. (2012). Refining the theory of basic individual values. *J Pers Soc Psychol*, *103*, 663–688.

Simon, S., & Connolly, J. (2020). What Do Science Teachers Value? In C. Corrigan, A. Buntting, A. Fitzgerald, & D. Jones (Eds.), *Values in Science Education*, *Vol. 1* (pp. 121–137). Springer.

Swaim, J.A., Maloni, M.J., Napshin, S.A., & Henley, A.B. (2014). Influences on student intention and behavior toward environmental sustainability. *J Bus Ethics*, *124*, 465–484.

UNESCO (2017). *Education for sustainable development goals*. UNESCO.

The field work concept in STEM education – International students' perspectives and expectations before an Erasmus+ course about climate change

Bouke van Gorp[2], Jardar Cyvin[1], Martina Calovi[1], Jakob B. Cyvin[1]

[1] *Norwegian University of Science and Technology (NTNU), Trondheim, Norway*

[2] *Utrecht University, Utrecht, the Netherlands*

e-mail: b.vangorp@uu.nl

Abstract

Pre-service teachers' understanding of fieldwork influences their use of fieldwork in climate change education. In this paper, we investigate how participants of the EduChange project perceive fieldwork. We analyse their answers from a sticky note exercise and questionnaire held during the EduChange course. These pre-service teachers display a rich understanding of fieldwork, and focus on its activating, situated pedagogy. However, they are not blind to the various barriers teachers may need to overcome to embed fieldwork in their teaching.

Keywords

fieldwork, climate change education, pre-service teachers

1. Introduction and theoretical background

Fieldwork, defined as out of classroom teaching where first-hand experience with the field is essential (Boyle et al., 2007, 300), is considered an important pedagogy in GEES (geography, earth science and environmental sciences) and STEM that has many potential benefits (Kent et al., 1997; France & Haigh 2018). Fieldwork also has great potential for climate change education (CCE) and broader education for sustainability (SDE), especially in its ability to overcome mechanisms of psychological distancing by contextualising and stimulating the affective dimension (Dillon, 2017; Jegstad et al., 2017; Monroe et al., 2019; Favier et al., 2021; Cyvin & Van Gorp, 2022; Remmen & Iversen, 2022).

However, being outdoors does not inherently mean effective teaching and learning for CCE. Effective fieldwork that leads to deeper learning requires thorough preparation and embedding of fieldwork into the curriculum (Oost et al., 2011; Remmen & Frøyland, 2014, 2015a,b). It also asks teachers to overcome practical hurdles (costs, timetables) and even to convince school management of its value. Educating pre-service teachers about the benefits of fieldwork for teaching wicked problems like climate change can help them feel well prepared to use it in their lessons. This research focuses on pre-service teachers and their perceptions of fieldwork. Since fieldwork can be a powerful tool and site for CCE, we want to know what our participants think about fieldwork to gauge whether they would be inclined to use it in their professional lives.

Our research is based on a designated international field course about innovating CCE created within the Erasmus+ project EduChange (educhange.net). The EduChange methodology focuses on student-centered, enquiry-based methods which apply photography, Virtual Reality, gamification, and place-based experiences (Panek et al., 2022). Students from four participating universities gained various fieldwork experiences during the common international field week. The entire course continues after this field week when participants apply the methodology while preparing a teaching activity related to climate change for a local school.

2. Methods

Two cohorts of EduChange participants shared their fieldwork perceptions, expectations, and experiences with the authors. This group may be self-selective, as climate change education and fieldwork were two important pillars of the course. Participants' fieldwork perceptions were collected at the beginning of the international field week using sticky notes (*n*=18, 2022; *n*=30, 2023). We asked the students about their vision of fieldwork as a pedagogical concept and their desired and expected types of field education. The 2023 cohort completed a supplementary questionnaire with questions regarding their prior experiences with fieldwork, whether they believe fieldwork has added value for education and which barriers to fieldwork they were aware of. An SDI, using an abductive approach, was used for analysis (Tjora, 2018). We made an additional inventory of the fieldwork activities students designed as part of the EduChange programme.

3. Results

The overall impression of the sticky notes and online questionnaire is that students have rich notions of fieldwork. Rich in several ways: we found both very elaborate answers and short almost poetic notions that capture 'grander' ideas such as 'learning from and in the world' or 'a classroom without walls!'. In the 2023 cohort, a few students filled their sticky note entirely: 'Fieldwork in my profession as teacher means taking learners outside the classroom and school building where learners actively participate in a learner-centered methodology in activities often located outside. Although 'the field' can also be an inside location but to learn something about that surrounding'. In their answers to the separate questions, some students stuck to one main idea, whereas others added new insights with each answer (see table 1).

Table 1. Comparison of two students in their answers to three of our questions

What is fieldwork?	
Doing things which you study theoretical, outside practical	Fieldwork is an educational tool to develop geographical skills such as mapping and it helps to add context and bridge the gap between theoretical concepts and visual / practical adaptations of those concepts
How to set it up?	
Depends of field. For climate change it should be with modern technologies and research.	Fieldwork should consist of various activities and different cognitive levels in order to contextualize different topics by showcasing local / real life examples from the outdoors and own environment
Added value?	
Yes, it is something unusual for children and they keep more attention	In my opinion, fieldwork adds value to teaching as it provides a contextualization of subject material, theories or concepts by experiences in a student's daily life and environment.

In short, their collective perception of fieldwork is that fieldwork is outside, offers first-hand, real-life experiences, often contains some type of data collection and makes education fun. Five students exclusively referred to data collection on their sticky notes. The sticky note exercise formed the opening of the fieldwork workshop. We shared our definition after the exercise to avoid any influence. A range of generic data collection techniques – 'tasks like observing, measuring, exploring' – as well as skills specific to disciplines (georadar or meteostation) were mentioned.

The rich notions can be explained by participants' familiarity with fieldwork. We asked the 2023 cohort about their fieldwork experiences as students, as teachers or guides. Of the 30 participants only two had no previous experience, the majority participated in fieldwork as students and eleven had (additional) experience as teachers or guides. Many of them have a background in geography, environmental sciences or ESD, where fieldwork is considered essential (France & Haigh, 2018). Apparently Covid_19 interfered little, only one student mentions this as a reason why their experience with fieldwork was limited. The 2023 cohort was asked whether they felt that fieldwork had added value for teaching. Some answered this question with a definitive 'yes' or 'of course' with an exclamation mark. Other answers reflected a similar obvious added value: 'as a biologist teaching outside is essential', 'usually we learn more' or 'exposing people to firsthand experiences is always very effective'.

3.1 Fieldwork dimensions

When zooming in on the answers, we see that participants focus on a number of dimensions of fieldwork as a teaching activity: location, didactics, benefits, impact, and conditions. Participants frequently referred to fieldwork didactics. We identified four common themes in their answers: active participation, experience, real-world and cooperation. Participants firstly refer to fieldwork as an active way of teaching, to them fieldwork is about learning by doing, active participation, hands-on application and self-learning. They secondly mention experiences as an important didactical element of fieldwork: fieldwork is an immersive activity, it is about being in the field, experiencing places, experiencing issues first-hand. For some respondents this experience also implies using multiple senses. Other answers explicitly state 'own experience' or contradict experience to knowledge gained through a book or a teacher talking. A third and related thread refers to the 'real world' connection of fieldwork. Students mention that fieldwork can make pupils experience or see what they read about, connect the theory to the real world, and thus make what is abstract concrete. As a result, fieldwork contextualizes learning, translates the examples from other places to the local context, to their own lives. Particularly in the 2022 cohort, students mention a fourth didactical element: cooperation. One student extends this to working with local people.

Participants not only name elements of fieldwork didactics, they also explain why these elements are important, or what the effect could be on teaching and learning. This is remarkable since few have actually set up fieldwork as teachers. We uncovered various strands of thought. Firstly, there are arguments made about variety: fieldwork as a novel way to learning that diversifies teaching methods. These comments imply that variation is good and serves a purpose: 'bring variation to your teaching so you can motivate a larger part of the group' or 'something unusual for children and they keep more attention'. Secondly, the answers also point at the mechanisms that make fieldwork effective: it is motivating and engaging: 'more motivating and give more interest in a topic' and 'open curiosity for new learning'. The answers thirdly refer to improved learning outcomes: 'should be better for our memory', 'pupils would think topics more interesting, ask more questions, learn / recollect more', 'it enriches students' learning experience, cause deeper learning also improve attitude to (science) education'.

A core characteristic of fieldwork is its location. Participants mentioned it takes place outside and used a range of expressions for this: 'outdoor', 'outside, in real environment', 'in the wild, not it the office', 'in situ / on the ground', 'outside in natural or urban environment'. In their answers we distinguish five perspectives on how fieldwork relates to 'regular' classroom teaching. For some fieldwork is the opposite of the classroom. They wrote about how fieldwork is different from indoor teaching, how it is more fun, and how certain things cannot be learned in the classroom: ‘it does not make sense teaching about nature sitting in a classroom’. The other participants connected the classroom and field, albeit in various ways. We firstly found broad notions of how the field adds something: ‘brings life to what you discuss in class’. Other statements hint at some kind of extension of classroom teaching: one student refers to skills that need to be practiced outdoor as well, thus implying that instruction can only partly be done in classroom. And finally, the connection was also explained in terms of sequence, suggesting fieldwork takes place after topics are discussed in the classroom: ‘seeing real-life examples of things you had studied previously’, ‘apply what they have been learning’. Two students refer to the possibility of bringing the outside in the classroom, for example by means of virtual reality.

3.2 Creating fieldwork?

During the entire EduChange course, students designed two educational activities. During field week, they first of all worked in international teams and designed an activity which is play-tested on the last day by all participants and teachers. Over the years, about a third to half of the play-tested activities contained an outdoor element. Students for example ran outside to photograph waste in the school surrounding or investigated urban heath islands using the Seppo app. Other play-tested activities used board games, role play or quizzes.

Back home, students worked in small teams and reached out to local schools (often where they do their internship). They designed a lesson or series of lessons. These teaching activities included a variety of outdoor activities – either in surrounding of school, in a nearby location connected to climate issues or in area that pupils would pick themselves. The students readily applied new technologies in connection to fieldwork – Storymaps as part of the preparation before entering the field, Seppo games to use in the field. The importance participants attach to fieldwork is reflected in activities designed by the 2020 cohort. They developed their activities in times of the first general lockdowns and conversion to online teaching. Still, they amongst others created an activity using a Storymap with optional fieldwork, another activity that could be done using VR and videos but does state ‘if possible in field’, an activity in school yard and activity that requires students to go on fieldtrip to woodlands area.

4. Discussion

Overall, the perceptions of fieldwork of our participants reflect important insights from the literature about effective implementation of fieldwork (e.g., Oost et al., 2011; Remmen & Frøyland, 2014; 2015 a & b; 2017; France & Haigh, 2018). Our students demonstrate an awareness of what can be learned with fieldwork (skills, content), of the potential added value (for example for motivation), and the requirements for effective fieldwork. Moreover, they recognize the importance of the authentic context and situated learning: fieldwork can be used to connect theory and abstract concepts to for real-world issues, what Lave & Venger (1991) called situated context.

Participants show awareness of what is needed to set up fieldwork and can identify potential obstacles, from practical issues such as weather, to organizational hassle (convincing school of its benefits, making room in a packed curriculum), or the challenges of being in the field with pupils: 'lazy students', 'bad selection of students' or 'kidz being kidz'. The lack of fellow teachers to run field work, or their lack of understanding of the value of fieldwork also form obstacles.

Our participants strongly lean towards student-centered approaches to fieldwork. One student explicitly warns that teachers should not be talking in the field all the time. Oost et al. (2011) emphasizes that enquiry-based fieldwork only leads to deep learning when two important conditions are met: fieldwork needs to be properly embedded, and all stages of the activity (including the preparation and debriefing) need to be approached in a student-centered mode. Teacher-centered introduction of topic or activity may put pupils in a more passive mode. The answers of our participants show awareness of the need to embed fieldwork: they mention the need for preparation and debriefing with pupils. Although the participants express a preference for student-centered approaches, their statements at times hint at a more mixed approach since they plan fieldwork after classroom teaching on the same topic.

5. Conclusion & further research

EduChange participants have a rich understanding of fieldwork, they recognize its value and are aware of the efforts required to organize it. Their understanding of fieldwork as active, student-centered, contextualized teaching has great potential for CCE and ESD. In the EduChange field course students experienced fieldwork, were trained in workshops and had the opportunity to apply it. We strongly believe that this holistic experience can support them in building their Pedagogical Content Knowledge regarding CCE and made them aware of the potential of fieldwork in this. In the safe learning space of the EduChange project they demonstrated this. However, follow up research is needed to establish the long-term impact on their professional life. Research by Emstad et al. (2020) has shown that extensive training does not guarantee teachers will use outdoor education in their teaching. Training may not be the key ingredient to them actually using it when the obstacles early career teacher face in school seem to big for them to overcome. We will therefore reach out to the five cohorts of EduChange participants to find out whether fieldwork has become part of their repertoire as teachers.

Acknowledgements

The Educhange field courses were supported by the EU Erasmus+ program, projects: 2020-1-CZ01-KA203-078349 and 2017-1-CZ01-KA203-035519.

References

Boyle, A., Maguire, S., Martin, A., Milsom, C., Nash, R., Rawlinson, S., Turner, A., Wurthmann, S., & Conchie, S. (2007). Fieldwork is good: the student perception and the affective domain. *Journal of Geography in Higher Education*, *31*(3), 299–317.

Cyvin, J. & Van Gorp, B. (2022). Fieldcourses and the "extended classroom", an overview of outdoor activities in the EduChange programme. In J. Panek et al. (Eds.), *EduChange methodology*. Palacky University Olomouc. https://doi.org/10.5507/prf.22.24461335

Dillon, J. (2017). *Towards a convergence between science and environmental education*. Routledge.

Emstad, A. B., Strømme, A. Knudsen, B., & Lysne, D.A. (2020). Bidrar uteskole i lærerutdanningen til uteskole i første yrkesår? [Does outdoor education in teacher education contribute to outdoor education during teachers' first year as professionals?]. *Acta Didactica*, *14*(2), Art. 8.

Favier, T., V. Gorp, B., Cyvin, J.B., & Cyvin, J. (2021). Learning to teach climate change: Students in teacher training and their progression in pedagogical content knowledge. *Journal of Geography in Higher Education*, *45*(4), 594–620.

France, D. & Haigh, M. (2018). Fieldwork@40: fieldwork in geography higher education. *Journal of Geography in Higher Education*, *42*(4), 498–514. doi.org/10.1080/03098265.2018.1515187.

Jegstad, K. M., Sinnes, A. T., & Gjøtterud, S. M. (2018). Science teacher education for sustainable development: From intensions to realization. *Nordic Studies in Science Education*, *14*(4), 350–367. http://dx.doi.org/10.5617/nordina.3263

Kent, M., Gilbertson, D., & Hunt, C. (1997). Fieldwork in geography teaching: A critical review of the literature and approaches. *Journal of Geography in Higher Education*, *21*(3), 313–332.

Lave, J. & Wenger, E. (1991). *Situated learning. Legitimate peripheral participation*. Cambridge University Press.

Monroe, M., Plate, R., Oxarart, A., Bowers, A., & Chaves, W. (2019). Identifying effective climate change education strategies: a systematic review of the research. *Environmental Education Research*, *25*(6), 791–812. doi.org/10.1080/13504622.2017.1360842

Oost, K., De Vries, B., & Van der Schee, J. (2011). Enquiry driven fieldwork as rich and powerful teaching strategy – school practices in secondary geography education in the Netherlands. *International Research in Geographical and Environmental Education*, *20*(4), 309–325.

Pánek, J. et al. (Eds.) (2022). *EduChange Methodology*. Palacký University Olomouc. https://doi.org/10.5507/prf.22.24461335

Remmen, K.B. & Frøyland, M. (2014). Implementation of guidelines for effective fieldwork designs: Exploring learning activities, learning processes, and student engagement in the classroom and the field. *International Research in Geographical and Environmental Education*, *23*(2), 103–125. https://doi.org/10.1080/10382046.2014.891424

Remmen, K. B. & Frøyland, M. (2015a). Supporting student learning processes during preparation, fieldwork, and follow-up work: Examples from upper secondary school in Norway. *Nordic Studies in Science Education*, *11*(1), 118–134. doi.org/10.5617/nordina.908

Remmen, K. B. & Frøyland, M. (2015b). What happens in classrooms after earth science fieldwork? Supporting student learning processes during follow-up activities. *International Research in Geographical and Environmental Education*, *24*(1), 24–42. doi.org/10.1080/10382046.2014.967114

Remmen, K. B. & Iversen, E. (2022). A scoping review of research on school-based outdoor education in the Nordic countries. *Journal of Adventure Education and Outdoor Learning*, doi.org/10.1080/14729679.2022.2027796

Tjora, A. (2018). *Qualitative Research as Stepwise - Deductive Induction*. Routledge.

The implementation of school-community-projects and the effects on students' sustainability consciousness

Mirte W. Linthorst, Sanne Korte, Michiel Doorman

Freudenthal Institute (FI), Utrecht University, the Netherlands

e-mail: m.w.linthorst@students.uu.nl

1. Background of the study

In Europe, the development of science disengagement among students in secondary education is an often-seen phenomenon (Howard, 2017; Osborne & Dillon, 2008; Sjøberg & Schreiner, 2019). As many European countries already experience a shortage of specialists in scientific oriented disciplines, it is important to get people motivated to pursue a career in science to keep up with the rapid growth of the science sector (Archer et al., 2013; STEM Alliance, 2017). Furthermore, societies face complex science-related problems, such as global warming, floods, droughts, and water and air pollution. As these problems, also known as Socio-Scientific Issues (SSIs), are becoming more and more present in our society, it is important to give attention to these issues in the classroom. This enables students to develop their civic competences, such as science-informed decision making (Zeidler & Nichols, 2009) and therefore become better prepared to face these problems in their future (Ariza et al., 2021).

One of the initiatives that helps to bring real-life problems such as SSIs into the classroom are School-Community-Projects (SCPs). The goal of an SCP is to establish partnerships between schools and their community, whereby relevant SSIs for the community are the subject of the project. Students are asked to use project-based working methods to find a solution to a yet unresolved chosen SSI by working together with members of the community and other stakeholders to give students a better understanding of the application of science in society and motivate them to engage in science (ICSE, n.d.).

SCPs are also expected to change students' sustainability consciousness (SC). SC is an individual's awareness and understanding of the principles and practices associated with sustainable development, whereby environmental, societal, and economic dimensions are considered (Gericke et al., 2019). It is known that SC dips during adolescence (Olsson & Gericke, 2016), making it important to search for effective adaptations in sustainability education such as SCPs to meet the needs of students.

As implementing an SCP in a school structure asks for a change in the curriculum and requires effort from the people involved, it is valuable to identify supportive elements for the implementation of such a project for long term use.

For example, involving and maintaining contact with all (external) community members and stakeholders can be challenging for (internal) school members (such as teachers and school leaders) that are involved in the project (Mathie & Wals, 2022) and therefore asks for attention. Furthermore, the development of students' SC through SCP is not known yet and can therefore be investigated.

2. Relation to the conference theme and dimension

As School-Community-Projects are based on open schooling approaches and are built around environmental issues, this research is suitable to fit the overall theme of this conference. The findings on the research questions are helpful for teachers and other school members that want to implement and sustain open schooling approaches in their curriculum. In addition, similar projects arising and searching for a long-term impact will benefit from the outcomes of this specific research. Therefore, the findings are mostly related to dimension 3, the structural dimension. The topic is addressed from the perspective of the internal school members and external stakeholders involved.

3. Set up of the study

The research questions of this study were:

1. What factors are important for the school organization and the community when implementing a School-Community-Project about energy management in the long term?
2. How does a School-Community-Project about sustainability affect 15-to-17-year-old students' sustainability consciousness?

To conduct the study, an SCP for approximately twenty 15-to-17-year-old pre-university students was designed. Besides students, other participants of the project were external stakeholders from the neighbourhood (such as from businesses or governments), and internal school members (such as teachers, and school leaders). To define the support that was needed for the participants to join the project, questionnaires were designed and filled in by the participants after the project. To measure students' SC, a pre- and post-questionnaire was used and a semi-structured group interview was set up, in which four students participated.

References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). Not girly, not sexy, not glamorous: Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture and Society*, *21*(1), 171–194. https://doi.org/10.1080/14681366.2012.748676

Ariza, M. R., Christodoulou, A., van Harskamp, M., Knippels, M. C. P. J., Kyza, E. A., Levinson, R., & Agesilaou, A. (2021). Socio-scientific inquiry-based learning as a means toward environmental citizenship. *Sustainability*, *13*(20), 11509. https://doi.org/10.3390/SU132011509

Gericke, N., Boeve-de Pauw, J., Berglund, T., & Olsson, D. (2019). The Ssustainability consciousness questionnaire: The theoretical development and empirical validation of an evaluation instrument for stakeholders working with sustainable development. *Sustainable Development*, *27*(1), 35–49. https://doi.org/10.1002/SD.1859

Howard, S. (2017). Issues with science education and student disengagement. *Science Teacher Education*, *79*, 24–35.

ICSE. (n.d.). *About MOST*. Retrieved June 13, 2022, from https://icse.eu/international-projects/most/?tab=about-most

Mathie, R. G., & Wals, A. E. J. (2022). *Whole school approaches to sustainability: Exemplary practices from around the world*. https://doi.org/10.18174/566782

Olsson, D., & Gericke, N. (2016). The adolescent dip in students' sustainability consciousness - Implications for education for sustainable development. *Journal of Environmental Education*, *47*(1), 35–51. https://doi.org/10.1080/00958964.2015.1075464

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol. 13). The Nuffield Foundation. https://www.nuffieldfoundation.org/wp-content/uploads/2019/12/Sci_Ed_in_Europe_Report_Final1.pdf

Sjøberg, S., & Schreiner, C. (2019). *ROSE (The Relevance of Science Education). The development, key findings and impacts of an international low cost comparative project. Final Report, Part 1 (of 2)*. Oslo University.

STEM Alliance. (2017). *STEM Education Factsheet*. http://www.stemalliance.eu/documents/99712/104016/STEM-Alliance-Fact-Sheet/4ae068f4-ca07-459a-92c9-17ff305341b1

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, *21*(2), 49–58. https://doi.org/10.1007/BF03173684

Use of new technologies for the challenges of the future

Mathias Klaus Kirf, Stephanie Eugster

University of Teacher Education St. Gallen

e-mail: mathias.kirf@phsg.ch

1. Smartfeld@St.Gallen: Tackling SDGs, future skills and physical computing in co-creation with active teachers and influenced by start-up spirit.

Smartfelds new project “Use of new technologies for the challenges of the future” (TecforFuture) combines STEM-education with education for sustainable development by fostering the experience of self-efficacy in the combined fields of new technologies and SDG-based challenges.

Smartfeld itself is an interdisciplinary initiative of the innovation network Startfeld, Empa, GBS St. Gallen, the University of Applied Sciences of Eastern Switzerland, the University of Teacher Education St. Gallen and the University of St. Gallen with the aim of promoting creativity and future competencies as well as making children and young people fit for the challenges of the digital age.

Within TecforFuture, the cooperation partners of Smartfeld, active teachers and their students combine their experiences and co-create new learning offers/workshops together, which benefit from the fact that (a) the interdisciplinarity, (b) the necessary expertise and (c) the necessary resources (time, finance, locations) are available and stimulate new exciting formats to arise.

The implementation of the workshop is carried out in the Switzerland Innovation Park Ost where start-ups work and make their ideas fly. This unusual, authentic location additionally contributes to the inspiration for students and teachers.

2. Co-creation of student and teacher educational settings with partner schools

The project aims at two different target groups, (a) students (Sek I, Sek II) and (b) their teachers.

Students: Most students in Switzerland are forced into career decisions within Sek I, latest Sek II, but in-school educational offers for self-efficacy experiences in the field of technology, entrepreneurship and interdisciplinary problem solving are still (very) rare. With this highly interdisciplinary project, students shall generate a broader view on the possible impact of STEM-competences and creativity on the SDG-challenges of the future.

Teachers: In contrast to Sek II, teachers of the Swiss Sek I are multidisciplinary educated, but most lack resources and/or sufficient IT/physical computing knowledge to integrate its potential into their lessons. Furthermore, some teachers shy away from the apparent complexity of open learning sessions often associated with student-centred computer-driven STEM tasks. Within the project`s spiral model, teachers are supported to improve on their own physical-computing skills, thus encouraging shared ownership.

3. TecforFuture: Problem statement and approach

Our problem statement:

Four out of ten students in Switzerland cannot explain climate change (Tagesanzeiger 2022). In an international comparison, the awareness of global issues of Swiss students is also low (Pisa, 2018). But already in 2015, 17 Sustainable Development Goals (SDGs) were defined as an urgent call for action by all countries in a global partnership.

To tackle the SDGs, innovative solutions are needed on a broad scale, translating into numerous creative and diverse minds working efficiently together, with an interdisciplinary understanding of the challenges and a mindset that individual capabilities can shape a powerful team. The pool for these diverse minds is represented by the future key-stakeholders (and the future mindset) for the creation and implementation of these innovative solutions: the young people.

Our approach:

With TecforFutures, Smartfeld expanded its innovative portfolio with a focus on using new technologies for the challenges of the future. Based on the SDGs, challenges are addressed by students by developing initial solution concepts (prototypes) with the help of new technologies.

The goal is, on the one hand, to enable learners to experience self-efficacy in the field of new technologies and to gain their own experience in implementing solution ideas, and on the other hand, to acquire methods and a mindset for solving problems and to recognize the resulting benefits of the generated application. This goal shall enhance the understanding of technology's broad potential to support solutions for the SDGs. However, a more generalized, but in the context of the SDGs, equally important goal is that as many young people as possible (Sek I, Sek II) shall experience for themselves in new learning settings that they already have what is the raw material of the future due to its "nonautomatability": Imagination and problem-solving skills that will make the difference for a more sustainable future.

The effective solution to achieve this goal lies within Smartfeld's specific DNA, as a proven and highly motivated incubator for innovative education created by strong partners.

We will present a) the project, b) its current implementation and c) lessons learned from the co-creative development- and implementation process from the view of Smartfeld as well as from the participating teachers.

Smartfeld at a glance:

In St.Gallen, the higher educational institutions have created a common lab to fuse technology and creativity for STEM-Education: Smartfeld. Smartfeld reaches out to 3500 pupils per year. Backed by foundations, it started in 2022 to develop, implement and run its new open source workshop "Use of new technologies for the challenges of the future" by combining the creative potential of its partners and active teachers in a co-creative approach based on the OECD Learning compass 2030. In short, it tackles SDGs, future skills and physical computing in co-creation with active teachers and influenced by start-up spirit.

Smartfeld's feedback loops represent a shortcut between teacher education and the students' educational system, thus "lessons learned", as well as established good practices, can rapidly be distributed and discussed between relevant stakeholders, as well as disseminated, e.g., via teacher training events, conferences and research-based formats.

Acknowledgements

We sincerely thank the Asuera Foundation, the Fourfold Foundation and the Hirschmann Foundation for their financial support of this project. We thank Bettina Gahler (Oberstufe Centrum, St.Gallen), Stefanie Egli and Daniel Stäger (Oberstufe Ost, St.Gallen) and their classes for the creative and co-constructive exchange of ideas and knowledge.

References

Balmer, D., & Cornehls, S. (2022). 'Vier von zehn Schülern in der Schweiz können den Klimawandel nicht erklären: Pisa Vergleich zum Klimawandel', Tages-Anzeiger SonntagsZeitung, 1 January [Online]. Available at https://www.tagesanzeiger.ch/vier-von-zehn-schuelern-in-der-schweiz-koennen-den-klimawandel-nicht-erklaeren-802317959712 (Accessed 8 March 2022).

Falloon, G., Hatzigianni, M., Bower, M., Forbes, A., & Stevenson, M. (2020). Understanding K-12 STEM education: A framework for developing STEM literacy. *Journal of Science Education and Technology*, *29*(3), 369–385. doi: 10.1007/s10956-020-09823-x.

Iwata, M., Pitkänen, K., Laru, J., & Mäkitalo, K. (2020). Exploring potentials and challenges to develop twenty-first century skills and computational thinking in K-12 maker education. *Frontiers in Education*, *5*. doi: 10.3389/feduc.2020.00087

Nguyen, T. P. L., Nguyen, T. H., & Tran, T. K. (2020). STEM education in secondary schools: teachers' perspective towards sustainable development. *Sustainability*, *12*(21), 8865. doi: 10.24200/jonus.vol4iss1pp300-315

OECD (2019). *OECD learning compass* 2030. Available at https://www.oecd.org/education/2030-project/teaching-and-learning/learning/ (Accessed 12 December 2022).

OECD (2020). *Are students ready to thrive in an interconnected world*? OECD Publishing. Available at https://read.oecd-ilibrary.org/education/pisa-2018-results-volume-vi_d5f68679-en (Accessed 14 March 2022).

United Nations (Ed.) (2015). Transforming our world: The 2030 agenda for sustainable development | Department of Economic and Social Affairs. Available at https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981 (Accessed 1 February 2023).

Our current society faces enormous environmental challenges. Now is the time to stand up for a sustainable future. This request for action also concerns our STEM education community to take the transformational potential of teaching and learning.

Teachers are decisive factors in ensuring the achievement of creative and sustainable learning outcomes in mathematics and science education, in fostering young peoples' competences and empowering them to become responsible and active citizens. We need to share good practices, research results and innovative classroom materials that allow for implementing approaches that support the implementation and scaling up of education for sustainability.

Educating the Educators (ETE) is an international conference series on professional development in STEM (science, technology, engineering and mathematics) education that brings together teacher educators, policy makers, teachers and various other stakeholders related to STEM education. The fourth edition of the ETE conference series was hosted by Utrecht University, ICSE and the Naturalis Biodiversity Center in the Netherlands, in collaboration with the MOST project.

ETE IV focused on implementing and scaling up innovative teaching approaches in STEM education with an emphasis on open schooling for sustainability education. The aim was to discuss different ways of working, the roles of teaching materials, and structures needed for innovations in STEM education. ETE IV featured both traditional and innovative formats to benefit of a diverse circle of participants from research, practice and policy. Vivid exchange and collaborative work were ensured through spaces for co-creation. This volume reflects the main topics of discussion and the participants' conference experiences.

ISBN
978-3-95987-274-4 E-Book