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Advancing Scientific Literacy in Climate Change Education through Collaborative, Evidence-Based Approaches

Maija Aksela,
LUMA Science Ambassador
University of Helsinki, Finland
(maija.aksela@helsinki.fi)

Abstract:
Promoting students' scientific literacy in the context of climate change requires effective, evidence-based educational strategies. This paper explores the collaborative efforts among scientists, science educators, schools, and society to enhance understanding of current scientific evidence, innovations, and constructive hope. Since 2010, Finland has implemented a holistic approach to climate change education through the LUMA (STEM) network, engaging students and teachers in formal, nonformal, and informal educational activities. Personalized learning, such as using students' questions as a starting point, and the co-design approach within design-based research, have proven effective in fostering meaningful collaboration and engagement. This paper also introduces a model of scientific literacy tailored to climate change education, emphasizing the importance of integrating novel scientific knowledge, processes, thinking, and the relationship between science, technology, and society at the students' level through collaborative efforts.

Keywords: Scientific Literacy, Climate Change Education, Collaborative Learning.

Resumo:
A promoção da literacia científica dos alunos no contexto das alterações climáticas exige estratégias educativas eficazes e baseadas em provas. Este documento explora os esforços de colaboração entre cientistas, educadores científicos, escolas e sociedade para melhorar a compreensão das actuais provas científicas, inovações e esperança construtiva. Desde 2010, a Finlândia implementou uma abordagem holística à educação sobre as alterações climáticas através da rede LUMA (STEM), envolvendo alunos e professores em actividades educativas formais, não formais e informais. A aprendizagem personalizada, como a utilização das perguntas dos alunos como ponto de partida, e a abordagem de co-design no âmbito da investigação baseada no design, revelaram-se eficazes na promoção de uma colaboração e envolvimento significativos. Este documento também introduz um modelo de literacia científica adaptado à educação para as alterações climáticas, salientando a importância de integrar novos conhecimentos científicos, processos, pensamento e a relação entre ciência, tecnologia e sociedade ao nível dos alunos através de esforços de colaboração.

Palavras-chave: Literacia científica, educação para as alterações climáticas, aprendizagem colaborativa.

Introduction

Climate change is a complex socio-scientific challenge (e.g., IPCC, 2023). Innovative education is essential for equipping society with the knowledge, skills, and motivation needed to address this issue (e.g., Muccione, Ewen & Vaghefi, 2025; Nusche, Fuster Rabella & Lauterbach, 2024). Developing a scientific orientation is one of the six key climate change competences that youth aspire to achieve (Taurinen et al., 2024). Employing engaging teaching methods, such as facilitating interactions with scientists, can greatly enhance environmental education for young students (Monroe et al., 2017). These approaches can inspire students to deepen their understanding of climate change (Ratinen, 2021). Moreover, fostering collaboration between universities, schools, and society (e.g., Ikävalko, Pernaa, & Aksela, 2024) is an effective strategy to advance education and empower student agency.

This paper explores the crucial role of scientific literacy for youth in enabling informed decisions and fostering constructive hope. It highlights the collaborative efforts of scientists, science educators, schools, and society to enhance students' scientific literacy through evidence-based education. One scientific literacy model (Miller, 1983) used in the context of climate change education is presented at the end of the paper.

The Finnish national core curriculum emphasizes the importance of sustainability education in fostering students' agency. Since 2010, the LUMA (STEM) network has played a crucial role in supporting this goal. Comprising 11 Finnish universities and 13 LUMA centres (www.luma.fi/en), the network fosters collaboration between universities, schools, and society to support the national curriculum (Aksela, Lundell & Ikavalko, 2020). The primary aim of the LUMA network is to engage students and teachers in math, science, and technology from early childhood to university through evidence-based education and collaboration. Its holistic approach includes formal, nonformal, and informal educational activities designed to engage students and teachers in climate change education. In Finland we trust on personalized learning approaches that cater to students' needs and interests.

Engaging with students by listening to their voices and addressing their questions is vital for fostering their understanding and involvement (e.g., Reilly et al., 2024; Rousell & Cutter-Mackenzie-Knowles, 2021). Young students often ask insightful, multidisciplinary questions that encompass scientific, societal, and ethical aspects (e.g., Tolppanen & Aksela, 2019). By addressing their inquiries—such as which questions have been explored, how research has been conducted, what gaps remain, the reliability of information, and available solutions (e.g., energy)—we can deepen their understanding of climate change and foster constructive hope (Ojala, 2011).

Evidence-Based Climate Change Activities through Design-Based Research

In the context of climate change education, our model of evidence-based education (Davies, 1999) leverages current research to effectively integrate science with learning. The co-design approach within design-based research facilitates this integration in a manner that is easily comprehensible for students. This framework has proven to be a valuable tool for fostering collaboration among various partners (Aksela, 2019; Aksela & Tolppanen, 2022). Through design-based research, the following outcomes can be achieved: 1) a new pedagogical solution or model for teaching climate change, 2) increased understanding of the development process, and 3) new knowledge about its teaching and implementation.

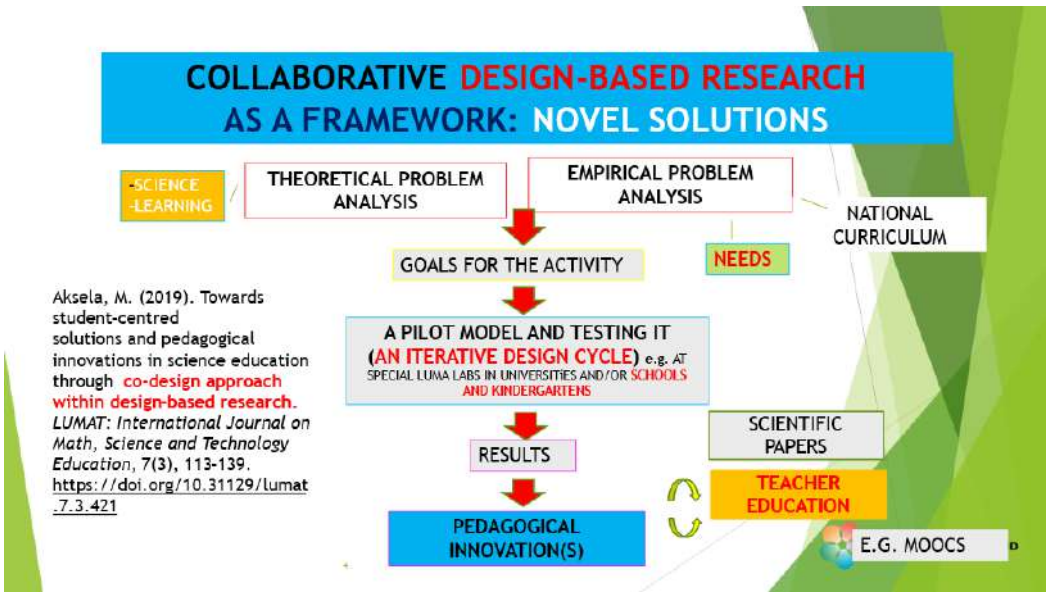

Figure 1: Collaborative design-based research as a framework for novel solutions (Aksela, 2019; Aksela & Tolppanen, 2022).

Starting from identified needs, the model aligns contemporary climate change research and education with educational goals and activities, involving scientists, science educators, schools, companies, and other societal stakeholders. Pilot models are tested with school students, teachers, and student teachers, with data collected through a range of formal, non-formal, and informal educational activities. These activities follow iterative cycles in design-based research. The outcomes, including also students' theses, learning tasks in material banks, papers, and publications, are utilized in teacher education.

Personalized learning approaches, such as using students' questions as a starting point, and the co-design approach within design-based research, have proven effective in fostering relevant collaboration and engagement. These LUMA (STEM) activities include the international Millennium Youth Science Camp, where students, university scientists, science educators, and specialists from different companies collaborate on authentic projects (Tolppanen & Aksela, 2014; Vesterinen, Tolppanen, & Aksela, 2016).

Personal approaches, like taking students' questions seriously, are an important part of climate change education. We have organized the international StarT LUMA programme (https://start.luma.fi/en/) since 2017, in which students have the opportunity to devise their own projects based on their questions and interests and share what they have learned globally. Sustainability issues related to climate change have been a key focus of the programme. The best solutions, presented as videos and learning diaries, have been collected in an open material bank on the StarT website for global use. Teachers have been found to play a central role in the project-based learning activities (Haatainen & Aksela, 2021; Markula & Aksela, 2022).

Talented teachers are seen as the main agents for a sustainable future. The LUMA network is closely integrated into both evidence-based pre-service and in-service training programs and its research (e.g., Aksela, Lundell & Ikävalko, 2020). It organizes the annual International Climate Change Forum (TCCF) with INAR scientists, providing a platform for teachers, scientists, and science educators to develop multidisciplinary activities for students (Aksela & Tolppanen, 2022). Research has demonstrated that teachers' perceived content knowledge (pCK) and

perceived pedagogical content knowledge (pPCK) in the context of climate change correlate with their self-efficacy, especially with items related to action (Herranen & Aksela, 2024). Teacher agency can be affected by (a) their background, especially their sustainability and environment-related teaching background, (b) cultural interactions, (c) the learning environment, (d) predominant discourses in society, and (e) their thoughts regarding the useful principles of climate change teaching (Sihvonen, Herranen, Uusi-Äijö, & Aksela, 2024). The evidence received has been important for co-designing relevant solutions for teacher education.

Students' questions have been an important part of the climate change education programme called Climate?, helping to make the topic relevant for students, activate student learning, and raise constructive hope for the future. During the programme, teachers from different countries received concrete ideas and examples of how to use students' questions as part of their climate education and were able to discuss their ideas and experiences with other teachers in the classroom using a student question-based pedagogy (Herranen & Aksela, 2019). The goal was to improve teachers' self-efficacy in using the pedagogy and to develop a student question-based pedagogy in climate change education as new didactic models, which teachers worldwide could then utilize in their teaching.

For instance, one our international research project is focusing on the topic of "Enacting Climate Change Education: Building student and teacher agency through representing scientists' practices in classrooms" and involves three countries (Australia, Finland, and Taiwan):
https://enactingclimatechangeeducation.deakin.edu.au/overview/

The Model of Scientific Literacy in Climate Change Education

A model of scientific literacy tailored to climate change education used in Finland highlights the importance of integrating scientific knowledge, processes, thinking, and the relationship between science, technology, and society through collaborative efforts. The model is designed to help students understand the complexities of climate change and develop the competencies needed to address it.

Scientific Knowledge: This component focuses on central concepts and phenomena related to climate change, such as the hydrogen economy. It emphasizes the connections between scientific knowledge and socio-scientific issues, helping students understand the broader implications of climate change.

Scientific Processes: This component involves inquiry methods, data analysis, and the study environment. It emphasizes the importance of validity and reliability in scientific research, helping students develop critical thinking and problem-solving skills.

Scientific Thinking: This component includes critical thinking, creative thinking, and systemic thinking. It encourages students to ask research questions, consider ethical and moral implications, and develop solutions to climate change-related problems.

Science-Technology-Society Relationship: This component emphasizes collaboration and a multidisciplinary approach to sustainability. It highlights the importance of ecological, economic, social, and cultural sustainability, and encourages students to explore careers in science and technology.

By integrating these components, the model aims to promote scientific literacy and student agency in climate change education. The co-design approach, involving collaboration between teachers, scientists, and science educators, ensures that the model is relevant and effective.

Conclusion

There are many pedagogical ways to promote students' scientific literacy through evidence-based education. Students need to learn about how to work with scientific evidence in the context of climate change as a part of developing their climate change competences on the base of their actions and constructive hope for the future. One relevant way to inform them about current evidence of climate change is through greater collaboration between scientists, schools, and society. The co-designing approach between partners and personalized approaches, like the use of students' questions, to engage them on climate change issues can help students learn more about the topic. It represents also a novel approach to teacher education, where

all participants learn collaboratively from each other in the context of climate change. The scientific literacy model presented above can prove useful for co-designing collaborative educational activities, even during teacher education, in the context of a multidisciplinary climate change education.

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