Co-designing Science Clubs for Non-formal STE(A)M Learning Environments through Design-based Research

Maija Aksela and Outi Haatainen

LUMAlab Gadolin (a part of LUMA Centre Finland), The Unit of Chemistry Teacher Education, Department of Chemistry, Faculty of Science, University of Helsinki, Finland

Abstract:

This pilot study explores the co-design of after-school science clubs as non-formal learning environments to promote culturally sustainable STE(A)M education. Using educational design-based research (Aksela, 2019) as a framework, the project was implemented through a collaboration between LUMAlab Gadolin (part of LUMA Centre Finland), the University of Helsinki's pre-service chemistry teacher education program, and primary schools in Helsinki. The science clubs were co-designed and piloted in 2024 between student teachers and teachers at schools. The clubs, aimed at children aged 9–11, followed a six-week structure centered on project-based learning and everyday science phenomena. A MOOC on project-based learning was built to support the co-design process. Preliminary findings suggest that co-designing science clubs fosters student-centered pedagogical innovations. Further research is needed to refine the model through additional design-based research cycles.

Keywords: Chemistry teacher education, non-formal learning, STEAM education, co-design, science clubs

Contact: maija.aksela@helsinki.fi

Introduction

There is a growing need to develop innovative pedagogical approaches that engage all students in science education and support inspiring, culturally sustainable teacher education (Ministry of Education and Culture, 2023). In response to this need, non-formal learning environments — such as after-school science clubs — could offer promising opportunities to complement formal education and foster interest in science, technology, engineering, arts, and mathematics (STE(A)M). Various types of non-formal learning environments have previously been developed within the LUMA Centre Finland (Aksela, Lundell & Ikävalko, 2020). These environments could also serve as platforms for continuous professional development for both pre-service and in-service teachers (e.g. Haatainen et al, 2024).

This study presents a co-designed science club model developed through a collaborative initiative between LUMAlab Gadolin (a part of LUMA Centre Finland), the University of Helsinki's Chemistry Teacher Education, and primary schools in Helsinki. The initiative is part of the international StarT programme coordinated by LUMA Centre Finland, a national science education network. The science clubs were designed to be student-centred and project-based, aligning with the principles of STE(A)M education and emphasizing real-world relevance, creativity, and interdisciplinary learning.

To guide the development and implementation of the clubs, we employed educational design-based research (Aksela, 2019, see Figure 1), which supports iterative co-design processes and the creation of contextually relevant pedagogical solutions. The project also integrates a MOOC on project-based learning (PBL), which serves as both an introduction for student teachers and a continuous learning opportunity for participating school teachers. PBL has been our research focus for years (e.g. Haatainen & Aksela, 2021; Haatainen, 2022).

The aim of this research is twofold:

1. To explore how student-centred science clubs can be co-designed for non-formal learning environments (RQ1)
2. To identify the pedagogical solutions that emerge from the co-design process involving student teachers and in-service teachers (RQ")

This paper presents preliminary findings from the pilot implementation of the science clubs in 2024–2025, highlighting the collaborative design process, the resulting club model, and its potential to enhance both student engagement and teacher learning in STE(A)M education.

Design-based research as framework for co-designing

Design-based research (DBR) offers a robust and iterative framework for developing and studying educational innovations in real-world settings. In this project, DBR was employed to guide the co-design of after-school science clubs as non-formal STE(A)M learning environments. The approach aligns with the LUMA Centre Finland's long-standing use of DBR to foster pedagogical innovation and culturally sustainable science education (e.g. Aksela, 2019, see Figure 1).

The DBR process in this study was structured around collaborative engagement between pre-service chemistry teachers, in-service primary school teachers, and university educators. The goal was to create a student-centred, project-based science club model that could serve both as a meaningful learning experience for pupils and a professional development opportunity for teachers.

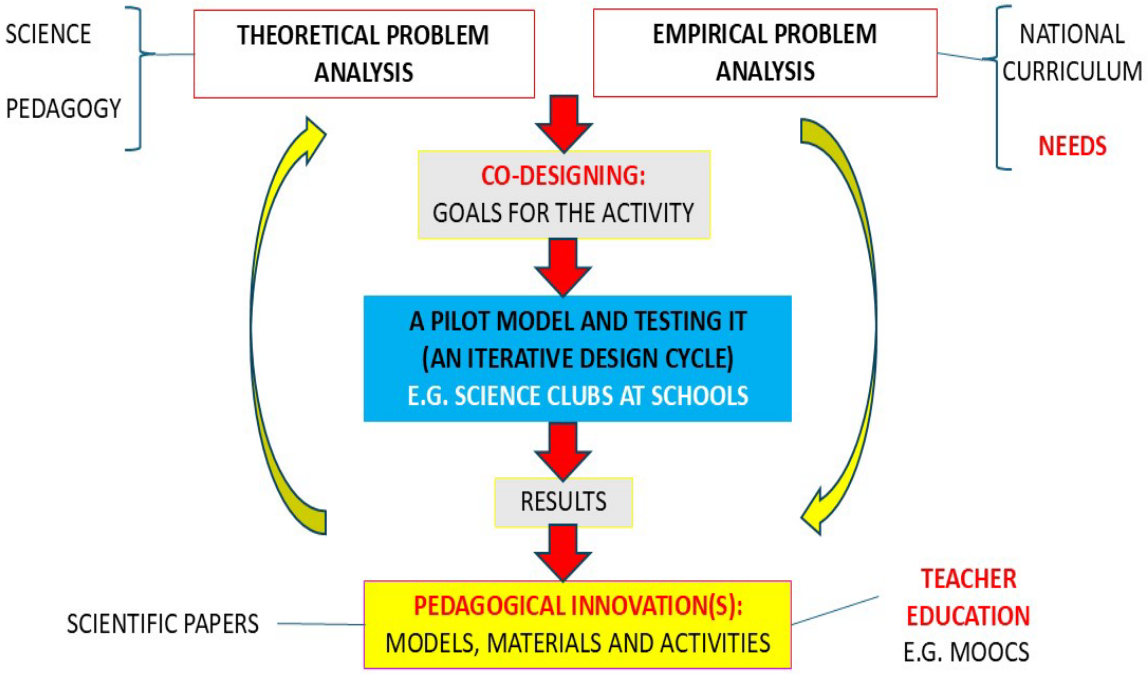

Figure 1. Educational design-based research (Aksela, 2019) as a framework tool for co-designing science clubs.

Results

The research questions are addressed in the following sections: first to the researh question (RQ1) and then to the second one (RQ2).

RQ1: Co-designing process for a science club

The co-design process began with a theoretical problem analysis through a MOOC course. Pre-service teachers enrolled in the University of Helsinki's "Everyday Chemistry" course (5 ECTS) were introduced to project-based learning (PBL) through a 1 ECTS MOOC. This course component provided foundational knowledge and examples from prior research to support the design process. The MOOC was also

offered as a voluntary continuous learning opportunity for participating school teachers.

Following this, student teachers and schoolteachers engaged in joint planning sessions, including an online meeting in February–March. These sessions marked the beginning of the co-design phase, where both groups collaboratively developed the structure and content of the science clubs. The clubs were then implemented in schools over a six-week period (March–May), with weekly 90-minute sessions. During this phase, student teachers acted as instructors, while in-service teachers served as mentors and co-learners, contributing their classroom experience and pedagogical insights.

The course for university students ends in reflection and presenting the clubs and projects made with the children in an international StarT LUMA webinar to share the experiences with international colleagues and to hear and learn from their experiences in turn. The co-design process is outlined in Figure 2.

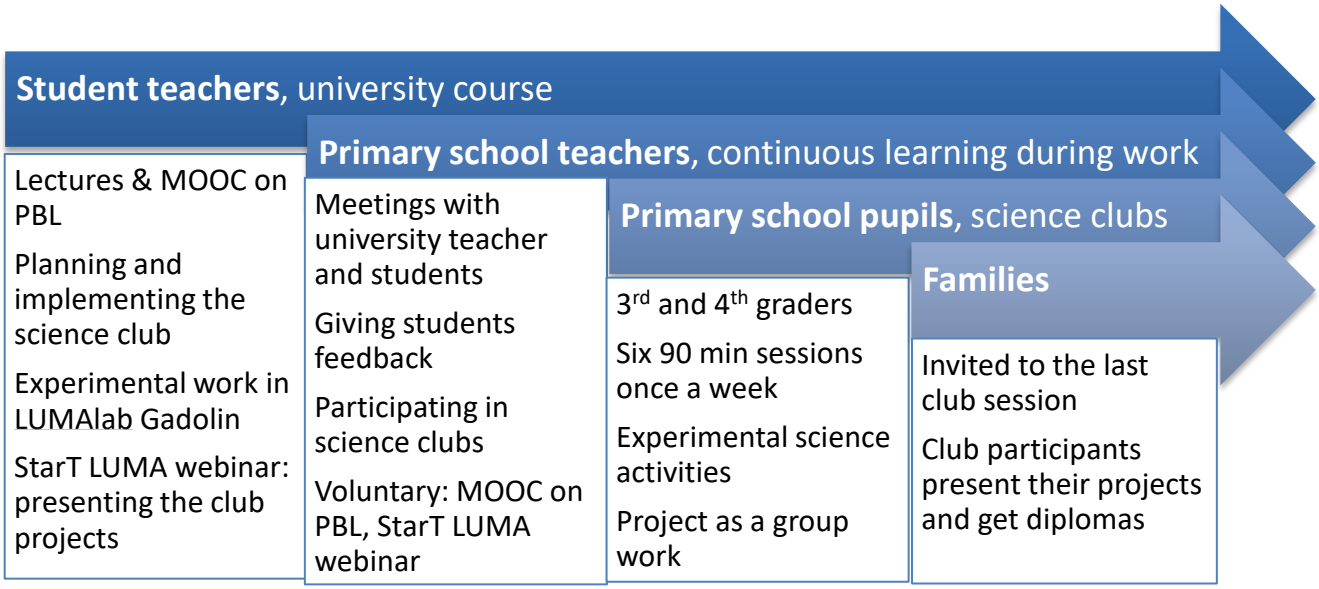

Figure 2. Co-design processes between student teachers and teachers at school.

RQ2: A Pedagogical model: A student-centred science club

The clubs were held once a week for six weeks with the theme "Natural Sciences in Our Life." Student teachers designed the session content as part of their university course, consulting school teachers and listening to participating children's wishes and questions. Each 90-minute session involved experimental activities that engaged the

children in STE(A)M and project work in groups. Content of the club session:

- **1st session:** Introductions and writing rules together, discussing natural sciences in our lives and interesting topics
- **2nd session:** Groups choose their own project-question and plan their project
- **3rd and 4th sessions:** Project related inquiry, experiments and discussions
- **5th session:** Planning the final session together and making project presentation
- **6th session**: a small ”science fair” In the final session, the participants presented their findings in person, with posters and videos as a support.

The projects designed by children were related to everyday phenomena, such as removing dirt from clothing with various cleaning solutions, or nature, e.g., investigating different kinds of rocks or plant growth and water. Additionally, other topics the children found interesting included space and the possibility of life on other planets.

Discussion and conclusions

The findings from this pilot study suggest that design-based research (DBR) can be a powerful framework for co-designing non-formal science education initiatives, such as after-school science clubs. The iterative and collaborative nature of DBR enabled the development of a student-centred, project-based club model that was both pedagogically sound and practically feasible.

One of the key strengths of the project was the integration of multiple stakeholders—pre-service teachers, in-service teachers, university educators, and primary school pupils—into the co-design process. This collaboration could foster mutual learning and professional growth during the process. Pre-service teachers gained valuable experience in planning and facilitating inquiry-based activities, while in-service teachers were introduced to new pedagogical strategies and project-based learning (PBL) approaches. The inclusion of a MOOC on PBL seems further to support this process by providing a shared theoretical foundation and practical tools for all participants.

The six-session structure of the science club model, culminating in a student-led science fair, allowed children to explore real-world phenomena through hands-on experiments and collaborative inquiry. The final session, which involved families,

added a community dimension that enhanced the relevance and visibility of the learning experience.

Reflective practices embedded in the DBR cycle—such as post-session discussions and participation in the international StarT LUMA webinar—were instrumental in refining the club model. These reflections highlighted both the successes and challenges of the implementation. For example, while the use of English in the MOOC was beneficial for internationalization, it posed difficulties for some participants. This insight points to the need for more accessible multilingual resources in future iterations or use AI opportunities for it.

Overall, the project demonstrates that co-designed science clubs can serve as effective non-formal learning environments that support culturally sustainable STE(A)M education. They offer a promising model for blended teacher education, combining formal coursework with practical, community-based experiences.

To build on these promising results, further research is needed. Additional DBR cycles should be conducted to test the model in diverse educational contexts and to gather more comprehensive data on its impact. Future studies should also explore how the model can be adapted for different age groups, subject areas, and cultural settings. Moreover, integrating feedback from both student teachers and in-service teachers will be essential for refining the pedagogical strategies and ensuring the model's scalability and sustainability.

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