STEMification - towards a framework for supporting teachers' professional development in PBL with a focus on engineering education transitions

Lisborg, Sanne; Hansen, Søren; Bertel, Lykke Brogaard; Møller Jeppesen, Mette; Dahl, Bettina; Otto, Sofie; Nielsen, Camilla Guldborg; Henriksen, Lars Bo; Krarup, Jakob Farian

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Work-in-Progress: STEMification - towards a framework for supporting teachers' professional development in PBL with a focus on engineering education transitions

Sanne Lisborg
Aalborg University, Denmark, *sali@plan.aau.dk*

Søren Hansen
Aalborg University, Denmark, *sha@plan.aau.dk*

Lykke Brogaard Bertel
Aalborg University, Denmark, *lykke@plan.aau.dk*

Mette Møller Jeppesen
Aalborg University, Denmark, *mmje@adm.aau.dk*

Bettina Dahl
Aalborg University, Denmark, *bdahls@plan.aau.dk*

Sofie Otto
Aalborg University, Denmark, *sio@plan.aau.dk*

Camilla Guldborg
Aalborg University, Denmark, *cgni@plan.aau.dk*

Lars Bo Henriksen
Aalborg University, Denmark, *lbh@plan.aau.dk*

Jakob Farian Krarup
University College of Northern Denmark, Denmark, *jfk@ucn.dk*

Summary

To ensure a more diverse group of engineering candidates in the future, increased attention to transitions is needed in STEM education, e.g. by implementing more student-centred and inclusive STEM teaching approaches and practices across all levels of education through professional development. In this abstract, we argue for a holistic understanding of transitions in engineering education both concerning *content* (transitions related to curriculum development and a shift in focus from scientific knowledge to STEM competencies); *cohesion* (transitions between subjects and transformation of disciplines toward integrated and interdisciplinary engineering education for sustainable development); and *continuity* (transitions in the education system through cross-institutional collaboration and coordinated pedagogical approaches). We introduce *STEMification* as a conceptual framework for facilitating engineering education transitions and trajectories, and as an approach to support teachers' professional development towards integrated and inclusive STEM teaching across all educational levels. The framework is developed within the Danish research project, LabSTEM North, and builds upon principles from problem-based learning, inquiry-based learning and creative platform learning to offer multiple pathways for supporting student motivation and the development of STEM competencies, applicable to all STEM disciplines at all levels of education.

Keywords: STEM, problem-based learning, engineering education transitions, design-based research, professional development

Type of contribution: Research extended abstracts

1 Introduction

There is a pressing need to better understand and ease 'transitions' in STEM education, both horizontally across subjects (Science, Technology, Engineering and Math) and vertically at all levels of education, if we are to establish a continuing interest in engineering education. Many students experience STEM teaching as abstract and difficult to relate to, why they lose interest in STEM during their school years (Osborne & Dilon, 2008). The decline interest in STEM, which is predicted to continue in the future, is both an industrial and societal problem as the lack of diverse and well-prepared engineering graduates affects both industry and society's ability to respond to demands for green transition and sustainable solutions as well as the digital transformation accelerated by emerging technologies (European Commission, 2015; CEDEFOP 2020; UNESCO 2021). Thus, new and inclusive ways of teaching the STEM disciplines are needed, focusing on complex and interdisciplinary problem solving and the development of transversal STEM competences (Bertel, Winther, Routhe & Kolmos, 2021).

In this extended abstract, we argue that cross-institutional collaboration and a broad focus on transitions can contribute to ensuring a diverse group of engineering graduates, who are well-equipped to contribute to the fulfilment of the Sustainable Development Goals (UNESCO, 2021). We argue that an integrated STEM approach is needed and explore its possible structure and potential as a professional development tool, based on the following research questions:

How can a focus on authentic problems (problem-based learning), personal motivation (inquiry-based learning), play and creativity (creative platform learning) facilitate an integrated framework for STEM teaching? And how can such a framework contribute as a professional development tool in teachers' cross-institutional and collaborative professional learning communities?

2 The LabSTEM North Project

The abstract is based on research and development conducted within LabSTEM North (2021-2024), a Danish design-based research project established to develop a framework for PBL-based and STEM-integrated teaching and to support interdisciplinary and cross-institutional collaboration to enhance students' interest in STEM disciplines throughout the entire education system (Christiansen, Bertel & Dahl, 2022). In the project, STEM-integrated teaching is understood as teaching practices where a minimum of two or more STEM subjects are addressed and integrated (e.g. through a PBL approach) with the overall aim of increasing student interest and diversity in STEM. So far, thirteen educational institutions with more than 80 teachers from primary schools, (technical and general) high schools, pre-college engineering and vocational schools, and higher education institutions in the northern region of Denmark participate in the project. Thus, a central part of the project is to gather knowledge of best practices from programs or initiatives particularly successful in ensuring diversity in STEM (Bertel, Jeppesen, Henriksen, Hansen & Dahl, 2022) as well as to develop new approaches and practices through accessible and sustainable cross-institutional collaboration in 'hybrid' teacher communities, where practitioners can co-create and share ideas, digital resources, and teaching materials (Christiansen, Bertel & Dahl, 2022). This is done through a design-based research approach where teachers develop cross-institutional and cross-disciplinary designs for STEM teaching. The proposed STEMification framework is based on the development and implementations of these teaching designs and is continually being tested and refined as the project progresses (Edelson, 2020).

3 STEMification: An integrative *and* diversified approach to STEM

As part of the LabSTEM North project, we have explored different ways in which motivation for STEM can be enhanced, resulting in what we call the *STEMification framework*. To motivate more students for STEM-related educations we argue, that working with authentic problems related to the STEM professions and in connection to a personal learning experience and inner desire for learning in a creative, playful learning environment is crucial across all levels of education. Figure 1 below illustrates how the different learning principles are combined in the framework. It is important to note that while the framework draws on and highlights distinct aspects of these pedagogical models and methods, the purpose is not to distinguish these from one another. Rather, they represent shared principles and approaches, proposing multiple potential pathways towards a common goal; to facilitate curiosity and participation in STEM and to ease educational transitions and create diverse learning trajectories.

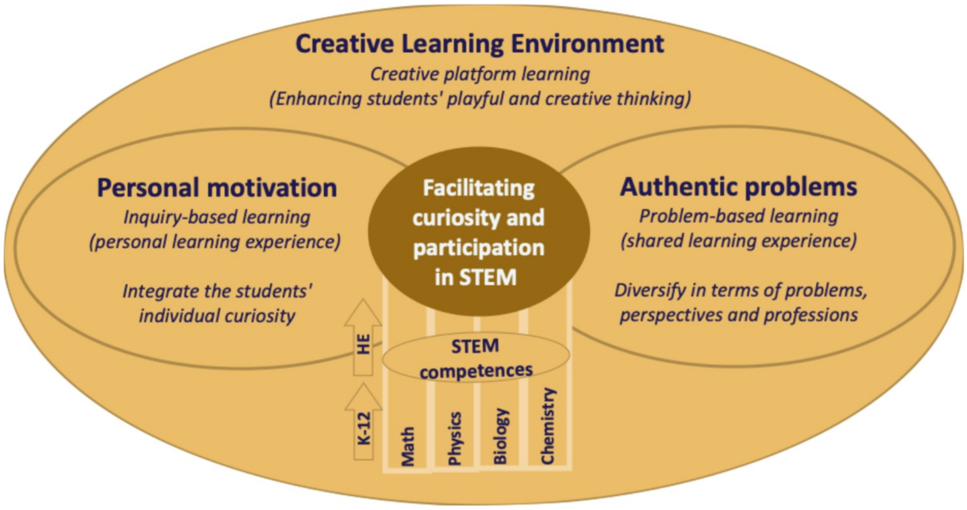

Figure 1. The STEMification framework

Transversal STEM competencies

As seen from figure 1, when teaching science (biology, chemistry, and physics) or mathematics, the content of the disciplines can be motivating to some students in and of itself, particularly if students believe they are capable within these subjects (Trujillo & Tanner, 2014; Webb-Williams, 2018; Bertel et al. 2022). This can be further encouraged by a focus on the transversal competences that belong to and bridge each of the four areas of STEM, such as *posing research questions, develop a hypothesis, designing an experiment to answer the question,* and *critically assess the results*. By implementing an integrated approach, students learn that these competencies are transversal, i.e. recognizable and applicable across disciplines, and that practicing them in one subject will facilitate not only a deeper understanding of the specific subject, but also learning in other, related STEM disciplines.

Authentic problems and problem-based learning

Working with authentic, real-life problems as highlighted in problem-based learning (PBL), can be very motivating to students particularly as the knowledge is contextualized and often put to practical use in concrete engineering design and problem-solving processes (Kolmos et al., 2013). A focus on real-life and complex problems acknowledges the contribution of different and multifaceted disciplines and highlights the need for interdisciplinary approaches to complex problem-solving (Bertel et al., 2021). This can be further reinforced if the teacher acts as a STEM role model that demonstrates how discipline-specific problems often represent broader societal challenges and thus the needs and pains that scientists and engineers face daily (Markula & Aksela, 2022).

Personal motivation and curiosity

Moreover, it is central to work with the student's personal motivation by encouraging them to ask and pursue questions, thus acting as an intrinsic motivator for the students' learning. Here, we are inspired by inquiry-based learning, where the student-driven investigation and engagement is the central element in the learning process (Pedaste et al., 2015; Bayram, Oskay, Erdem, Özgür & Şen, 2013). Asking questions and seeking answers can be highly motivating, if the questions are born out of curiosity – a desire for new knowledge that becomes an *inner* motivator. Therefore, one of the pedagogical principles in STEMification, is to facilitate learning processes that are grounded in the student's *own* curiosity. If we want to motivate more students for STEM-related educations, the real-life problems the students are working on must be related to a personal inner desire for learning; a burning curiosity to know more.

Creative Learning Environment

Finally, for students to engage with real-world problems and learning based on their own curiosity, the learning environment must offer focus, inspiration, and creative collaboration. Focus, to be able to connect a discipline, or a problem, to personal knowledge and experiences. Inspiration, facilitated by a teacher to help students connect their questions and experiences to disciplines. Creative collaboration, with the teacher and other students to co-construct new knowledge. It is a process of blending the content of disciplines with problems and personal experiences and where students engage with an open and curious mind, because the fear of failing and sense of judgement is suspended. This aspect of the STEMification framework is inspired by the creative platform (Hansen & Byrge 2009; Byrge & Hansen 2009).

4 STEMification in practice: Testing the framework as a professional development tool in interdisciplinary and cross-institutional teacher learning communities

So far, we have introduced the framework to 75 teachers and tested it in three iterations of workshops focusing on developing it in collaboration with the teachers. The first three iterations of workshops have highlighted a need to broaden our understanding of transitions in K-12 STEM and engineering education. Whereas the problem with existing STEM education is often that too many are excluded from participating in the problem solving due to gender, ethnicity, neurodiversity, or other socio-economic factors, this problem cannot be reduced to merely a matter of 'fixing the leaky pipeline' (European Parliament, 2021; CEDEFOP, 2020). Rather, increased attention to the narrative of 'what makes a good engineer' is needed as well as an overall strengthening of content, cohesion, and continuity in the transformation of STEM in the entire education system.

Content here refers to the need to redirect the focus from subjects and syllabi to competences and pressing issues and transitions in society and technology, i.e. sustainability issues and the impact of rapid digitalization accelerated by emerging technologies on society through working with authentic real-life problems across STEM disciplines at all levels. Particularly in higher engineering education, these problems and solutions should represent and serve as good examples of the students´ future profession as well (Kolmos & Holgaard, 2017). *Cohesion*, on the other hand, refers to transitions *between* subjects and disciplines, i.e. to create solutions to global sustainability problems we need to work with an integrative and coherent approach, accepting that a single discipline alone cannot solve the complex wicked problems and global challenges of today and tomorrow. Thus, it is essential that STEM education becomes less silo-oriented and more engaged with interdisciplinary problem-solving, also involving the Arts and Humanities, sometimes referred to as

STEAM (Perignat & Katz-Buonincontro, 2019). Finally, we argue that it is important to establish *continuity* across all education levels through collaboration to create a community of practice that facilitates successful transition, e.g. by ensuring that pedagogical frameworks and approaches are inclusive and recognizable as the student proceeds through the educational system (Bertel et al, 2022). Thus, the STEM teaching that students encounter from primary school to higher education must be based on real-life problems that facilitate inclusion and enable diverse learning trajectories in STEM.

5 Conclusion and next steps

In this abstract we propose the *STEMification framework* as and approach to support teachers' professional development in PBL and explore how a focus on authentic problems, personal motivation, play and creativity can facilitate integrated and diverse approaches to STEM teaching. The framework encompasses principles from both problem-based learning, inquiry-based learning and creative platform learning and is developed in collaboration with teachers in cross-institutional and cross-disciplinary professional learning communities in the design-based research project LabSTEM North. The framework is proposed as a way to ease transitions in science and engineering education both in terms of content, cohesion, and continuity. In line with the used DBR approach the empirical results from the workshops and subsequent observations of teaching as well as student/teacher interviews will inform the further analysis of the STEMification framework's applicability as a professional development tool at all levels of education. The results will be shared through research papers, digital resources, and teaching materials appliable in different levels of STEM and engineering education.

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