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Key principles of integrated STEM: cross-fertilization between Engineering and secondary STEM education

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Secondary STEM education and engineering higher education: a match made in heaven?

Highly educated STEM professionals, and engineers in particular, increasingly top the lists of most wanted profiles on the European labour market (European Commission, 2020). For higher STEM education to be able to deliver the required number of STEM graduates, a sufficiently high number of students should be enrolled at the start. However, by the end of secondary education (SE), a large share of pupils who were initially enrolled in a STEM programme, opt out of STEM when enrolling in higher education (HE) (De Meester et al., 2020; Kersanszki & Simonics, 2022). From the pupils who do enroll in a HE STEM programme, an alarmingly high proportion lacks the attitude and skills necessary to successfully complete their first year (Broos et al., 2021). Moreover, pre- and in-service teachers lack sofisticated Nature of Engineering (NoE) views (Kaya, 2020), inhibiting transfer of the NoE to their pupils. This insufficient preparedness and lack of understanding of the NoE urges a new, integrated approach to STEM SE (European Committee of the Regions, 2019), that can be inspired by practices in the first years of HE engineering programmes (Engberg & Wolniak, 2013). In turn, SE practices in integrated STEM (iSTEM) can also inform HE engineering programmes. In summary: HE engineering programmes and iSTEM SE share two common goals: (1) motivating students for STEM studies/careers, and (2) preparing students for these studies and careers. This workshop aims to enhance cross-fertilization between iSTEM SE and engineering HE, in the pursuit of these goals.

A guideline for designing qualitative integrated STEM projects in six key principles

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Six key principles form the basis of iSTEM education that helps pupils develop competences required in engineering and science programmes as well as in future STEM careers (Thibaut et al., 2018; Flemish Government, 2015). These principles are: (1) problem-centered learning and problem solving, (2) integration of learning contents from different STEM subjects, (3) modeling, (4) inquiry-based learning, (5) design-based learning, and (6) cooperative learning. In an ERASMUS+ partnership project launched in 2021, five European HE institutions joined forces with the primary goal to embed these principles in (i)STEM teacher education programmes in a sustainable and effective manner (CiSTEM², 2021). Through an online training that immerses student teachers in each of the six key principles, the partner institutions aim to prepare these future (i)STEM teachers to incorporate the principles in their own classroom practices.

Finding common ground through interactive group discussions

In this workshop we want to exchange good practices and stumbling blocks with respect to each of the six key principles of high-quality iSTEM education. Two central questions will be addressed: (1) How are the six iSTEM key principles embedded in HE engineering programmes (e.g., projects in the bachelor programme, theoretical courses, interdisciplinary courses…)? (2) What can (i)STEM teacher education and engineering HE learn from each other regarding these key principles to achieve their two common goals?

Small group discussions and interactive media (PollEverywhere, padlet, lucidchart, …) will be used to gather input from the public and summarize participant take-away. Via the interactive workshop activities outlined below, we want to enable participants in identifying actions and good practices for their education practice (specifically in assessing project quality, implementation and student competence training and evaluation) based on the iSTEM key principles.

(1) We open the workshop by presenting the six key principles and their implementation in STEM SE and (i)STEM teacher education.
(2) Together with the participants, we derive indicators of successful classroom implementation of each of these principles. The participants are invited to share specific examples from their practice in engineering HE to enrich the meaning of these indicators.
(3) We reflect upon the implementation in current SE and HE STEM programmes: which principles are strongly integrated, and which deserve more attention? Do SE and HE STEM implementations encounter the same struggles and opportunities? Can we get to a common understanding of practices underpinning qualitative STEM education?
(4) Additionally, we will focus on how to evaluate students' competences related to the iSTEM key principles.
(5) Finally, we want to introduce a tool to train STEM teachers and secondary school pupils in some of the iSTEM key principles. With the participants, we reflect on the usefulness of this tool for iSTEM SE and for their own HE STEM practices.
(6) We ask the participants to identify two action points for their HE engineering programme as well as for STEM teacher education with respect to the iSTEM key principles and with the aim of creating truly inspiring, competence-oriented integrated STEM education.

Outcomes of the group discussion

During the workshop the relative importance of the six iSTEM key principles in secondary and higher education and out-of-school-initiatives was discussed, along with concrete examples of practices associated with each principle. The participants agreed on the importance of problem-centered and cooperative work, along with integration between the STEM-disciplines. This further triggered the discussion about the semantics of STEM versus STEAM education, where the importance of creative thinking (be it imbedded in the A-discipline or inherently underlying the S, T, E and M-disciplines) was elaborated on. The CiSTEM^2-results, measuring the activation of the six iSTEM key principles during the iSTEM design process of multidisciplinary teams, were shared. Participants acknowledged the importance, but also the challenging nature of meaningful, deep, integrating links between the STEM-disciplines.

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