

## Epilogue

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Reflecting on the articles in the special issue, we may observe that there is broad and strong support for the idea of strengthening STEM education but that there is a lack of clarity about what STEM is or should be. The main argument for this support is in the role STEM plays in our highly technological society, and the need to prepare students for this technological society in general, and more specifically for STEM jobs. However, beneath this general consensus lies a multitude of ideas about what STEM is and how it should be taught. Here, we may refer to the issues English (2017) distinguishes. She observes that there is no consensus about,

- The definition of STEM,
- The level of integration that should be strived for,
- The individual discipline representation,
- How to ensure equity in access,
- The extension of STEM to STEAM.

All five points are related to the conceptualization of STEM; that is, what STEM entails, how it is to be shaped in practice, and how it is compiled by its constituting parts. Sometimes it seems that STEM is supposed to be everything to everyone. Clarification of the different roles STEM should play and perhaps prioritization of these roles would be useful. Much of the recent literature has been centered on the “E” in STEM since it is a field that has not always been included in the past, especially in K-12. Much more research needs to be conducted to determine how different types of goals might be best accomplished by different types and levels of integration.

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Closely related to these five points is the issue of instructional design. There is well-documented concern about the quality of STEM lessons (Carter, Chalmers, Cooper, & Nason, 2017). This special issue offers some potentially fruitful directions in this respect, such as the framework for curriculum development that Carter et al. (2017) offer, the suggestion of English (2017) to use modeling and engineering design as a means for designing integrated STEM instruction, and Atwood-Blaine and Huffman's (2017) proposal to use games in education. Nevertheless, much work still has to be done. This also holds for STEM in early childhood education. Research by Tippet and Milford (2017) suggests that there are good opportunities for fruitful STEM education for this age group.

The challenges in instructional design are closely interwoven with pedagogy. The articles in this special issue make it clear that teaching STEM in PreK-16 must change in both content and delivery. Clarifying the meaning of STEM as well as restructuring the content that should be the focus in school is a crucial first step. However, changes in what content should be taught and what programs are offered will have considerable implications for teacher preparation and professionalization. Most countries currently have separate sets of standards that outline what science and mathematics content should be taught. If and when the content of those change, as suggested by the articles in this issue, what does this mean for teacher professionalization? And how do we empower STEM teachers to be a part of changing the way in which subjects are taught? Today's classroom teacher is an expert in their particular content domain, so we will need to develop professional development and preparation programs that focus on STEM content as well as problem-solving, communication, and critical thinking (i.e., twenty-first century skills). Additionally, teachers will need to be able to integrate a variety of more sophisticated technologies into their instruction and may need to develop techno-mathematics literacies themselves (TmLs, van der Wal, Bakker, & Drijvers, 2017).

Twenty-first century skills and STEM goals involving habits of mind, inquiry, and reasoning appear to be generally accepted. Indeed, these goals of twenty-first century skills and habits of mind are apparent in all disciplines. What is unique to STEM and how STEM can best contribute to these goals needs to be clarified and researched. Additionally, it may be argued that there is need for more clarity on subject matter goals, as is, for instance, advocated by Gravemeijer, Stephan, Julie, Lin and Ohtani (2017) for mathematics education. They offer a broad palette of potential inroads to seek out what goals have to be aimed for, in order to prepare students for participating in society of the twenty-first century. In a similar vein, van der Wal et al. (2017) offer a concrete example of how goals that are relevant for the future can be generated by analyzing the work of engineers, in order to identify the Techno-mathematical Literacies (TmL) that engineers need in the twenty-first century. In connection with the latter, we may note that many TmL can be situated at the boundary of subject matter and general twenty-first century skills. We might argue that exactly those boundary skills need further exploration—as twenty-first century skills cannot exist in thin air. In addition to TmL's, it seems likely that TsL's and TeL's etc. will also need to be developed to provide bases for research with all boundaries, not just mathematical ones or just for engineers. Certainly, the new imaging capabilities affect the sciences from biology to astronomy and the effects of these deserve careful study. Furthermore, technology conceptual understandings and skills in and of themselves within STEM need further clarification.

Elaborating on the contributions to this special issue, we may advocate for studies from a discipline-specific perspective. English's (2017) example of how engineering might contribute offers some direction on how studies from a discipline-specific perspective might shed light on the contribution a specific discipline may offer to STEM integration. On the other hand, studies investigating the need for a discipline specific learning progression, are necessary for establishing how far integration is desirable or possible. To this we might add the need to make an inventory of applications of a given discipline that fall outside the STEM domain. In a similar vein, there is a need to investigate the connections and overlap with related disciplines, such as computational science and computational thinking.

In conclusion, we may point to the following topics for further research, instructional design, and/or collaborative investigation:

1. With an eye to the future of STEM:

- The conceptualization of STEM; what STEM entails, how it is to be shaped in practice, and how it is composed by its constituting parts.
- Theories, guidelines and practices for the design of high quality of STEM lessons.
- STEM pedagogy; especially concerning orchestrating integrated lessons, and fostering twenty-first century-related skills, such as, among others, habits of mind, inquiry, and reasoning.
- STEM teacher professionalization; in connection to the above topics.

2. With an eye to STEM for the future:

- Subject matter goals; concerning subject-matter specific goals, goals related to applications and modeling, and goals situated at the boundary of subject matter and general twenty-first century skills.
- Studies from a discipline-specific perspective; both looking at possibilities and at obstacles.
- Connections and overlap with related disciplines, such as computational science and computational thinking.

This list offers us a firm reminder that we are only at the beginning of an exciting and challenging journey. We hope that this special issue can function as stepping stone for further progress on this route.

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