Int J of Sci and Math Educ (2017) 15 (Suppl 1):S1–S4
DOI 10.1007/s10763-017-9815-5

Introduction to this Special Issue

Frances Lawrenz[1] · Koeno Gravemeijer[2] · Michelle Stephan[3]

Published online: 27 March 2017

Research about science, technology, engineering, and mathematics (STEM) for the future and the future of STEM is a rich field. A population with strong understanding of STEM is key to the successful future of the world. Effective life-long STEM education is the mechanism for providing that understanding. Now is the opportune time to consider the many theories related to the future of STEM as well as the many innovative ideas for structuring STEM education for the future. Consider, for example, how informatization and globalization has changed the world which today's students will enter. We speak of *STEM for the future* as well as the *future of STEM* to highlight an important if subtle difference. In *the future of STEM*, the emphasis is on building on what we know, and how we can use new technologies and teaching approaches to improve STEM education. The goal is of course also to prepare students for their future, but the future itself does not seem to be leading. In *STEM for the future*, it is the future that is leading and the central question is, what do we need to do to interact effectively with and to help shape that future? In the following, we will briefly summarize the content of this Special Issue, which includes a variety of empirical research, secondary analysis, review and theoretical articles on the emerging paths for STEM education.

The Future of STEM

There is broad support for the idea that the STEM disciplines should get extra attention in light of the prominent role that they play in the highly technological society of the twenty-first century. On the issue of what form this extra attention should get opinions

✉ Koeno Gravemeijer
koeno@gravemeijer.nl

1 University of Minnesota, Minneapolis, MN, USA

2 Eindhoven University of Technology, Eindhoven, Netherlands

3 University of North Carolina at Charlotte, Charlotte, NC, USA

diverge widely. In this issue, English (2017) tries to create some order in the wide variety of perspectives by distinguishing five core issues. The first concerns the multitude of perspectives on STEM education, and the lack of an accepted definition of what STEM entails. The second concerns the approaches to STEM integration. Here, she points to the tension between the high level of integration that is propagated by some on the basis of the integrated character of STEM at the workplace, and the demands of the mono-disciplines that are stressed by others. Further, there is the issue of describing actual forms of integration. The third issue concerns the unbalanced representation of certain disciplines within STEM instruction. Often, the various disciplines do not get the same attention in the STEM mix. She argues for a larger place for engineering, while acknowledging the privileged position of science and mathematics. The fourth and fifth issue concerns the equity in access to STEM education, and the extension of STEM to STEAM. The advocacy for the integration of modeling and engineering design as a powerful means for integrating STEM is elucidated with an example of how such learning affordances can be capitalized on. She further offers a framework for categorizing integrated STEM instruction.

Next to the wide variety of perspectives on STEM and the tensions that come with it, there is also a serious concern about the limitations in much current STEM teaching and learning. In their article in this issue, Carter, Chalmers, Cooper and Nason (2017) argue that more often than not such curriculum units are not mediating the construction of in-depth STEM knowledge. Building on an extensive literature review, they propose three types of big ideas that can be used to generate integrated STEM curriculum units that overcome this limitation. They suggest designing curriculum about the following types of big ideas: *within-discipline big ideas that have application in other STEM disciplines*, *cross-discipline big ideas*, and *encompassing big ideas*. This forms the basis for a six-component framework for curriculum development, which helps to concretize the concepts and make it more accessible to curriculum developers. They provide an example illustrating their important ideas to guide future research in this area.

STEM curricula may take various forms, using a variety of tools. This is shown by Atwood-Blaine and Huffman (2017), who explore the impact of an ipad gaming device on the interactions middle school students had with the displays at a science center. The study included a control group of students who interacted with the displays in a traditional manner and an experiment group that used an ipad game to structure their interactions with the science center. Interestingly, they found that girls interacted with the science center artifacts differently than did the boys. Their results have implications for designing learning experiences for students who explore more informal science environments.

Typical of the STEM movement is that not only the importance of the STEM disciplines is put forward, but that it is also advocated to expand the group of students STEM is to be taught to—which may also include Pre-Kindergarten (Pre-K) students. In their contribution, Tippett and Milford (2017) provide a data based argument for how and why STEM education is implemented in the Pre-K grades. They used a protocol for determining the STEM characteristics of lessons while they observed two Pre-K teachers. Utilizing this protocol allowed them to discern the types of activities the teachers were using with Pre-K students and how well they were aligned to strong STEM activities. Tippett and Milford also interviewed and surveyed multiple elementary stakeholders, including parents, to understand their viewpoints on integrating STEM in the early grades.

STEM for the Future

Next to building on what we know, and how we can use new technologies and teaching approaches to improve STEM education, we will have to consider, what goals we will have to pursue to prepare students for the future. Van der Wal, Bakker and Drijvers (2017) try to find some answers to this question by investigating the workplace practices of engineers. In doing so, they zoom in on the so-called Techno-mathematical Literacies (TmL) that engineers need in the twenty-first century. To identify these TmL, 14 semi-structured interviews were conducted with engineers with a background in different educational tracks in higher professional education (e.g. civil, chemical, biotechnical, and mechanical engineering). As a result of the data analysis, seven commonly used TmL are identified: data literacy, software skills, technical communication skills, sense of error, sense of number, technical creativity, and technical drawing skills. Engineers also noted a discrepancy between their education and workplace needs; they characterized mathematics in their education as an island with limited relevance. These findings lead to recommendations for the future of STEM in higher technical professional education that can help its students to learn the STEM for the future.

Van der Wal et al. (2017) focus on engineering in the context of STEM. However, it may also be argued that mathematics deserves focused attention. Gravemeijer, Stephan, Lin, Julie and Ohtani (2017) subscribe to this position while pointing to the way computerization affects mathematics and vice versa. They further assert that, applications of mathematics also concern a variety of non-STEM fields, such as, social sciences, finance, logistics and risk analysis. Like Van der Wal et al., they also focus on the goals of mathematics education, however their aim is much more ambitious. They want to engage the readers in a broad discussion about what mathematics education will be needed to prepare students for their future. Since machines will do all mathematical calculations in the future, both content and pedagogy will need to change. They explore what the changes that are taking place in the world around us under influence of digitalization and globalization, might mean for the goals of mathematics education. In relation to this they discuss how the so-called twenty-first century skills might be pursued in mathematics education. The main thrust, however, is on charting the demands of the twenty-first century from the perspective of work and employability. Here they employ three lenses: the *character* of mathematics in the workplace, the *competencies* that one needs in a setting where computers do the mathematical calculations, and the *mathematical topics* that deserve more (and less) attention in the twenty-first century society. They briefly discuss mathematics for everyday life, and close with a list of propositions that are meant to spark this discussion on this issue.

References

Atwood-Blaine, D. & Huffman, D. (2017). Mobile gaming and student interactions in a Science Center: The future of gaming in Science education. *International Journal of Science and Mathematics Education.* (this issue).

Carter, M., Chalmers, C., Cooper, T. & Nason, R. (2017). Implementing “big ideas” to advance the teaching and learning of science, technology, engineering, and mathematics (STEM). *International Journal of Science and Mathematics Education.* (this issue).

English, L. (2017). Advancing Elementary and Middle School STEM Education. *International Journal of Science and Mathematics Education.* (this issue).

Gravemeijer, K., Stephan, M., Lin, F., Julie, C. & Ohtani, M. (2017). What mathematics education may prepare students for the society of the future? *International Journal for Science and Mathematics Education*. (this issue).

Tippett, C.D. & Milford, T.M. (2017). Findings from a Pre-Kindergarten classroom: Making the case for STEM in early childhood education. *International Journal of Science and Mathematics Education*. (this issue).

Van der Wal, N.J., Bakker, A. & Drijvers, P. (2017). Which Techno-mathematical Literacies are essential STEM skills for engineers of the future? *International Journal of Science and Mathematics Education*. (this issue).