MULTIDISCIPLINARITY IN TEACHING STEM THROUGH MODELLING: IMPLICATIONS FOR TEACHER EDUCATION

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TOPICS: Curricular approaches to integrating mathematics and sciences; importance of mathematical modelling and interdisciplinarity for studying and learning STEM; the role of technology in connecting mathematics, arts, and sciences.

BACKGROUND AND AIMS

In our presentation, we discuss possibilities for multidisciplinarity in teacher education and challenge a conventional view on Science, Technology, Engineering, and Mathematics (STEM) teacher upbringing. Our overarching claim is that the existence of the STEM acronym does not guarantee a coherent and cohesive approach to STEM teacher education and STEM learning. We start by reflecting on the development of mathematics and science over the last few centuries and juxtaposing it with changes in mathematics and science education at K-16+ levels over the last hundred years. Then, we consider how the present educational system is not necessarily conducive to the adoption of authentic and humanistic multidisciplinary approaches to science and mathematics learning (Galili, 2011; Hottecke, Henke, & Riess, 2010).

The ongoing resurgence of calls to create robust STEM education for 21st century and to build bridges between the STEM fields (Li, Wang, Xiao, & Froyd, 2020) indicates that this goals has not been achieved yet. What is needed, is to develop an approach for STEM education that incorporates epistemological and pedagogical commonalities and tensions between different fields and implement it in teacher education. For example, "mathematics and science have often proceeded along parallel tracks, with mathematics focused on 'problem solving' while science has focused on 'inquiry'" (Li & Schoenfeld, 2019, p. 7). Moreover, educating students in STEM by teachers who likely lack the necessary multidisciplinary content background and have limited knowledge in the history and philosophy of STEM, is problematic. Consequently, many students perceive STEM as a group of loosely connected fields without acquiring the skills and abilities to traverse the fields' boundaries. Thus, it is not surprising that despite the ongoing STEM education efforts, the interest in STEM has stagnated over recent decades (Chachashvili-Bolotin, Lissitsa, & Milner-Bolotin, 2021; Chachashvili-Bolotin, Milner-Bolotin, & Lissitsa, 2016).

The tensions between teaching different STEM subjects are clearly visible in the current mathematics and science education (Ben-David Kolikant, Martinovic, & Milner-Bolotin, 2020; Martinovic & Milner-Bolotin, 2020). While in Canada teacher education varies from province to province, we have observed some common challenges in preparing future STEM teachers, which could be alleviated through collaboration within and between multidisciplinary teams of educators. We also observed how the expectation that the use of technology will automatically coalesce the STEM fields has not materialized.

One approach to deal with these issues is what Henderson et al. (2017) call, a *Discipline-based Education Research (DBER)*. It is grounded in the idea that education in each of the STEM fields benefits from research that unites the specific content, culture, and methods of the discipline with the general discipline of education research. The authors further envision establishing a cross-discipline STEM DBER alliance, as a way for improving STEM research and teaching, and for creating a unified voice to dialogue with policy makers.

Our multi-year collaboration has shown that a way forward in any authentic multidisciplinary teaching approach may be to "re-emphasize the nature … of [each] STEM [discipline]—as a sense-making activity" (Li & Schoenfeld, 2019, p. 1) and to strive towards enriching the students' experiences of the discipline. We agree with Hallström and Schönborn (2019) that "models and modelling can be used as a basis to foster an integrated and authentic STEM education and STEM literacy" (p. 1). Kertil and Gurel (2016) emphasize that teaching modelling requires more interpretive skills from teachers which is a challenge that could be addressed through multidisciplinary collaborations, such as ours.

In one of our latest publications (Martinovic & Milner-Bolotin, 2021), we explored four well-known frameworks: Kolb's Experiential Learning Cycle (Kolb, 1984); Gardiner's Framework for Epistemic Control (Gardiner, 2020); Model-Based Inquiry Learning (Windschitl, Thompson, & Braaten, 2008), and the framework for teaching modelling (Carlson, Wickstrom, Burroughs, & Fulton, 2016). As a result, we proposed an *Educational Framework for Modelling in STEM* which describes both teacher and student roles in the modelling cycle. We further used this framework to suggest how it could be implemented in teacher pre-service education and in-service professional development. This framework may be helpful in addressing the challenges mentioned above. By introducing students and teachers to the process of modelling, we can start building the common STEM language and move beyond the acronym to create authentic and humanistic STEM learning environments.

REFERENCES:

Ben-David Kolikant, Y., Martinovic, D., & Milner-Bolotin, M. (2020). Introduction: STEM teachers and teaching in the era of change. In Y. Ben-David Kolikant, D. Martinovic, & M. Milner-Bolotin (Eds.), *STEM Teachers and Teaching in the Digital Era: Professional expectations and advancement in 21st Century Schools* (pp. 1-18). Cham, Switzerland: Springer.

Carlson, M. A., Wickstrom, M. H., Burroughs, E. A., & Fulton, E. W. (2016). A case for mathematical modeling in the elementary school classroom. In C. R. Hirsch & A. R. McDuffie (Eds.), *Mathematical modeling and modeling mathematics* (pp. 121-129). Reston, VA: National Council of Teachers of Mathematics.

Chachashvili-Bolotin, S., Lissitsa, S., & Milner-Bolotin, M. (2021). *STEM enrollment of second-generation immigrant students with high-skilled parents*. Paper presented at the STEM in Education Conference 2020, Vancouver.

Chachashvili-Bolotin, S., Milner-Bolotin, M., & Lissitsa, S. (2016). Examination of factors predicting secondary students' interest in tertiary STEM education *International Journal of Science Education, 38*(2), 366-390. doi:10.1080/09500693.2016.1143137

Galili, I. (2011). Promotion of Cultural Content Knowledge through the use of the history and philosophy of science. *Science & Education*. doi:10.1007/s11191-011-9376-x

Gardiner, P. (2020). Learning to think together: Creativity, interdisciplinary collaboration and epistemic control. *Thinking Skills and Creativity, 38*, 100749. doi:https://doi.org/10.1016/j.tsc.2020.100749

Hallström, J., & Schönborn, K. J. (2019). Models and modelling for authentic STEM education: Reinforcing the argument. *International Journal of STEM Education, 6*, 22. doi:10.1186/s40594-019-0178-z

Henderson, C., Connolly, M., Dolan, E. L., Finkelstein, N., Franklin, S., Malcom, S., . . . John, K. S. (2017). Towards the STEM DBER Alliance: Why we need a discipline-based STEM education research community. International Journal of STEM Education. *International Journal of STEM Education, 4*(14). doi:10.1186/s40594-017-0076-1

Hottecke, D., Henke, A., & Riess, F. (2010). Implementing History and Philosophy in Science Teaching: Strategies, Methods, Results and Experiences from the European HIPST Project. *Science & Education*(December 2010), 29.

Kertil, M., & Gurel, C. (2016). Mathematical modeling: A bridge to STEM education. *International Journal of Education in Mathematics, Science and Technology, 4*(1), 44-55.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development* (Vol. 1). Englewood Cliffs, NJ: Prentice-Hall.

Li, Y., & Schoenfeld, A. H. (2019). Problematizing teaching and learning mathematics as "given" in STEM education. *International Journal of STEM Education, 6*(44). doi:10.1186/s40594-019-0197-9

Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: a systematic review of journal publications. *International Journal of STEM Education, 7*(1), 11. doi:10.1186/s40594-020-00207-6

Martinovic, D., & Milner-Bolotin, M. (2020). Discussion: Teacher Professional Development in the Era of Change. In Y. Ben-David Kolikant, D. Martinovic, & M. Milner-Bolotin (Eds.), *STEM Teachers and Teaching in the Era of Change: Professional expectations and advancement in 21st Century Schools* (pp. 185-197). Cham, Switzerland: Springer.

Martinovic, D., & Milner-Bolotin, M. (2021). Examination of modelling in K-12 STEM teacher education: Connecting theory with practice. *STEM Education, 1*(4), 279-298. doi:https://doi.org/10.3934/steme.2021018

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education, 92*(5), 941-967. doi:https://doi.org/10.1002/sce.20259