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Editorial Note: Teacher Professional Development in STEM Education

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ABSTRACT: In line with the substantial interest in STEM (science, technology, engineering, and mathematics) education and the major projects in STEM curriculum development around the world, efforts should be particularly made to increase the supply of STEM teachers through proper and effective teacher professional development. Although there have been a number of studies related to teacher professional development for individual subject training in science, technology, engineering and mathematics, quality research on professional development for teachers to develop their capacity for adopting the integrative and cross-disciplinary approaches advocated in STEM education remains in its infancy. The theme of this special issue is two-fold: (a) to provide researchers and practitioners in STEM education with a scholarly platform for reflecting on what challenges and impediments STEM teachers have encountered, and (b) to exchange new theoretical and practical insights gained from empirical research on designing, enacting and evaluating professional development programmes for building teachers' capacity in STEM education.

Keywords: STEM education, Teacher professional development, Teacher capacity building, Teacher education

1. Introduction

The acronym "STEM" (science, technology, engineering, and mathematics) has been a theme among global educators who have called for K-12 education reforms that will boost the competitiveness of the next generation of children by nurturing their problem-solving ability and creativity (Chai et al., 2020a, 2020b; Li et al., 2020). STEM education refers to "solving problems that draw on concepts and procedures from mathematics and science while incorporating the teamwork and design methodology of engineering and using appropriate technology" (Shaughnessy, 2013, p. 324). Simply put, STEM serves as a means to integrate the disciplines of science, mathematics, technology and engineering into practical applications to tackle and address authentic, real-world problems (Geng et al., 2019; Huang et al., 2020a, 2020b; Knowles et al., 2018; Wang et al., 2020). In fact, STEM competencies are not only required within but also outside of STEM occupations (Dai et al., 2021; Lin et al., 2021a, 2021b; Williams et al., 2019). In the long term, it is foreseen that STEM as an integrative cross-disciplinary subject can enhance students' problem-solving, critical and analytical thinking skills, and enculture them to be constructive and innovative citizens (Brown et al., 2011; So et al., 2020).

The significance of STEM education in today's digital world cannot be underestimated (Chai et al, 2021; Li et al., 2020; Williams et al., 2019). Nevertheless, the majority of K-12 teachers who are now engaged in supporting and facilitating STEM learning activities in schools have been trained within their own subject discipline (usually science, information technology, or mathematics) when pursuing their teacher education studies (Aslam et al., 2018; Cavlazoglu et al., 2017; Geng et al., 2019; Knowles et al., 2018). Thus, they may not be comfortable implementing the integrative and cross-disciplinary approaches advocated in STEM education (Margot et al., 2019; Rich et al., 2018; Wang et al., 2020; Weng et al., 2020). In line with the global interest in STEM education and the national efforts in STEM curriculum development, efforts should be made particularly in building teachers' STEM teaching capacity through proper and effective professional development training (Brand, 2020; Chai et al. 2020a, 2020b; Lin et al., 2021a).

In fact, teacher professional development is always important in pedagogical and curricular reforms (Desimone, 2009; Guskey, 2002; Jong, 2016, 2019a, 2019b). There should be no exception as STEM education is being put in place. In general, the capacity building elements of (a) content focus, (b) use of models and modeling, (c) active learning, (d) collaboration, (e) coaching and expert support, (f) feedback and reflection, and (g) sustained duration, are regarded as the keys to framing and shaping effective teacher professional development (Darling-Hammond et al., 2017). Although there have been a number of studies related to teacher professional development in science, technology, engineering, or mathematics individually, quality research related to professional development for teachers in developing their capacity for adopting the integrative and cross-disciplinary approaches advocated in STEM education remains in its infancy (Aslam et al., 2018; Chai et al., 2020a, 2020b; Geng et al., 2019; Lau et al., 2020; Li et al., 2020; Rinke et al., 2016; Weng et al., 2020).

As suggested by the title, this special issue aims (a) to provide researchers and practitioners in STEM education with a scholarly platform for reflecting on what challenges and impediments that STEM teachers have encountered, and (b) to exchange new theoretical and practical insights gained from empirical research on designing, enacting, and evaluating professional development programmes for building teachers' capacity in STEM education.

2. Overview of the papers contributed to this special issue

A total of 48 papers were submitted to this special issue. After a rigorous double-blind review process, 11 papers were accepted. The accepted papers were authored by 39 STEM education researchers from Australia, Austria, Hong Kong, Korea, Luxembourg, Singapore, United States, Taiwan, and Thailand. Among these 11 papers, eight are related to in-service teacher/ leader professional development on STEM education and three are related to pre-service teacher training on STEM education.

The first paper, "Teachers' Professional Development with Peer Coaching to Support Students with Intellectual Disabilities in STEM Learning," is contributed by So, He, Cheng, Lee, and Li. Adopting peer coaching as a teacher professional development strategy to support special education school teachers in collaboratively planning and implementing STEM learning activities, So et al. examined effective practices that facilitated intellectually-disabled students to complete the STEM learning tasks and the disparities that influenced the peer coaching process. This study provides the field with new insights into developing capacity-building training for special education school teachers on scaffolding and engaging intellectually-disabled students in STEM education. More specifically, the paper describes the use of technologies to support STEM learning tasks, while balancing inquiry-based learning challenges and students' abilities, while managing teachers' lack of pedagogical strategies.

The second paper, "Investigating Affordances and Tensions in STEM Applied Learning Programme from Practitioners' Sensemaking," is contributed by Wen, Wu, and He. Conducting a STEM learning programme for secondary education, Wen et al. explored the affordances and tensions of school leaders and teachers that emerged in the process of implementing STEM education in schools. The affordances include (a) the common understanding about the essence of STEM learning shared by leaders and teachers, (b) the positive effect of the national initiative of lifelong learning and the elimination of testing related to STEM education, and (c) the flexibility and authority of school-based implementation of STEM education. The tensions include (a) the conflict between examination demands and designed learning outcomes of STEM education, (b) the STEM teacher professional development received by the school teachers and leaders, and (c) the allocation of curriculum time and cost of materials pertaining to STEM learning.

The third paper, "Building STEM in Schools: An Australian Cross-Case Analysis," is contributed by Falloon, Stevenson, Beswick, Fraser, and Geiger. The context for Falloon et al.'s study is the implementation of a national STEM education capacity building project for primary and secondary school leaders that employs a generic learning environment model proposed by the Organisation for Economic Cooperation and Development. In this study, Falloon et al. investigated the factors influencing the development of different schools' STEM profiles, and identified the unique approaches and leadership strategies each adopted in designing STEM curriculum for meeting the learning needs of their diverse students. This work emphasizes the important role of principals in communicating a clear, evidence-based vision for STEM education in schools, and highlights the complex interaction of professional development, leadership, curriculum design, pedagogy, and school culture in developing effective school-based learning programmes and activities for STEM education.

The fourth paper, "Exploring Taiwanese Teachers' Preferences for STEM Teaching in Relation to their Perceptions of STEM Learning," is contributed by Lai. She designed a series of professional development training sessions for secondary school teachers, during which she examined the teachers' contextual preferences when implementing STEM learning activities. The study reveals that teachers' perception of collaboration is the key element in articulating their preference for STEM activities and their attitude toward STEM learning. Moreover, their preference for technical support and classroom interaction positively correlates with their perceptions of higher-order thinking and collaboration, while activity flexibility and teaching assistance positively correlate with their attitude toward STEM learning. This work gives the field a new perspective to design and enact capacity building strategies that address teachers' actual needs in STEM education through creating a collaborative STEM teacher community.

The fifth paper, “Design Principles for Effective Teacher Professional Development in Integrated STEM Education: A Systematic Review,” is contributed by Lo. Through a systematic review of the related literature, Lo synthesized 10 design principles for framing and shaping effective teacher professional development programmes/ activities for integrated STEM education. These principles can be divided into seven categories: (a) content focus, (b) use of models and modelling, (c) active learning, (d) collaboration, (e) coaching and expert support, (f) feedback and reflection, and (g) sustained duration. The study identifies content knowledge, pedagogical content knowledge, and sample STEM instructional materials as the three most frequently reported elements of effective teacher professional development pertaining to integrated STEM education. The 10 principles shed light on designing capacity building programmes for STEM teachers and addressing the potential challenges to integrated STEM education.

The sixth paper, “Teacher Professional Development on Self-Determination Theory-Based Design Thinking in STEM Education,” is contributed by Chiu, Chai, Williams, and Lin. Drawing on the self-determination theory (SDT), Chiu et al. created a professional development training programme, based on the paradigm of design thinking, to help secondary teachers learn effective STEM teaching and instructional practices. Using a quasi-experimental method (SDT-based Vs. non-SDT-based), they showed that integrating SDT elements into the process of STEM teaching and learning could promote both teachers’ and students’ perceived competence and intrinsic motivation towards design thinking. This study highlights the importance of the SDT-based teacher-support components (autonomy, structure and involvement) in STEM education, and it contributes to developing an SDT-based pedagogical framework for guiding teachers on how to foster students’ motivational disposition towards design thinking.

The seventh paper, “Infusing Computational Thinking into STEM Teaching: From Professional Development to Classroom Practice,” is contributed by Jocius, O’Byrne, Albert, Joshi, Robinson, and Andrews. Based on the 3C (code, connect, and create) framework, Jocius et al. developed and carried out a STEM professional development programme for secondary school teachers on how to pedagogically infuse the idea of computational thinking (CT) into their teaching, and then explored how these teachers implemented their CT-infused lessons in practice. Jocius et al. identified three major pedagogical supports (articulating a key purpose for CT infusion, scaffolding, and student collaboration) that the teachers used as they taught their CT-infused lessons; they also revealed the barriers that made the teachers adapt or abandon their lessons. This study sheds light on how to support teachers in applying STEM professional development content to classroom practices, and future research on CT infusion into secondary classrooms.

The eighth paper, “Better Together: Mathematics and Science Pre-Service Teachers’ Sensemaking about STEM,” is contributed by Lawson, Herrick, and Rosenberg. In the context of secondary mathematics and science teacher education, based on the sense-making theory, Lawson et al. explored how pre-service teachers acquired and deepened their understanding of STEM and STEM education through the course of collective sense-making. Although the facilitation of STEM learning is regarded as a challenging task for pre-service teachers who teach a range of subjects, this work offers the field an empirical example of how teachers can collaboratively work together through drawing on one another’s subject-based knowledge. It also shows that focusing on STEM learning through discipline-based practices, data, and appropriate technologies is an effective approach to supporting pre-service teachers as they develop STEM education practices.

The ninth paper, “Using an Enhanced Video-engagement Innovation to Support STEM Teachers’ Professional Development in Technology-Based Instruction,” is contributed by Ng and Park. In the context of secondary mathematics teacher education, grounded in a blended learning paradigm, Ng et al. designed, implemented and evaluated a video-based pedagogical approach to supporting pre-service teachers in STEM learning. The instructional programme used the following techniques in that support: (a) delivering an individualized viewing experience, (b) keeping a noticing record, (c) providing a guiding framework, and (d) facilitating a combination of individual and collaborative reflections. In the study, they showed that this approach could effectively draw the pre-service teachers’ attention to different aspects of technology-enhanced mathematics instructions related to STEM education. Capturing the dynamic processes of learners’ actions rather than just their final “answer,” this video-based pedagogical approach is effective in facilitating pre-service teachers’ reflections about the evolution of learners’ mathematical thinking as the students engage in STEM learning activities.

The tenth paper, “Integrated STEAM Approach in Outdoor Trails with Elementary School Pre-service Teachers,” is contributed by Haas, Kreis, and Lavicza. In the context of primary school teacher education, Haas et al. investigated how pre-service teachers, using an integrated STEAM pedagogical framework, worked in groups to design STEAM learning activities, using various technologies (e.g., GPS, augmented reality and digital modelling) for use in authentic outdoor trail experiences. Through hierarchical cluster analysis of these learning activities, Haas et al. identified three different patterned clusters, including (a) trails with mainly mathematics tasks, (b) trails with combined mathematics and engineering tasks, and (c) trails with STEAM tasks. This study provides the field with new inspiration for how to empower pre-service teachers to use technologies in the course of designing and implementing STEAM-based learning and teaching activities in outdoor environments.

The eleventh paper, "Implementation of an Andragogical Teacher Professional Development Training Program for Boosting TPACK in STEM Education: The Essential Role of a Personalized Learning System," is contributed by Chaipidech, Kajonmanee, Chaipah, Panjaburee, and Srisawasdi. Adopting a theory of adult learning and harnessing a TPACK-oriented personalized learning system, Chaipidech et al. developed a TPACK-based professional development training programme for secondary teachers with the aim of building the teachers' capacity in STEM education from the perspectives of (a) self-concept, (b) role of experience, (c) readiness to learn, (d) orientation to learning, (e) internal motivation, and (f) need to know. The results of this study highlight the effectiveness of incorporating andragogical principles and practices, as well as adopting the personalized learning system, in designing and implementing teacher professional development training on STEM education.

3. Conclusion

In the past few decades, many promising educational reforms and innovations have failed because the programmes did not help teachers develop their capacity to employ those reforms and innovations (Fullan, 2007; Jong, 2016, 2019a; 2019b). Although STEM education places significant emphasis on students' self-directed and constructive role in the learning process (Chai et al., 2021; Huang et al., 2020a, 2020b; Li, 2020; Lin et al., 2021b; Williams et al., 2019), teachers still do play a crucial role in supporting students in achieving the learning goals that underlie the STEM learning activities (Cavlazoglu et al., 2017; Geng et al., 2019; Lau et al., 2020; Lin et al., 2021a; Margot et al., 2019; Weng et al., 2020). We believe that the 11 papers published in this special issue can provide the field with new inspiration to design, implement, and evaluate professional development programmes for empowering teachers to develop effective pedagogical practices for STEM education.

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