Science, Technology, Engineering, and Mathematics (STEM) Education in University: Pre-service Teachers' Perceptions

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https://doi.org/10.24191/ajue.v18i3.18951

Received: 2 December 2021
Accepted: 12 July 2022
Date Published Online: 31 July 2022
Published: 31 July 2022

Abstract: Science, Technology, Engineering, and Mathematics (STEM) education, an integration of the four disciplines, has been promoted in schools and universities in Malaysia. However, the teachers' readiness in applying STEM has been an apprehension of not only the school administrators, but also the public. The implementation of STEM is observed from the teachers' abilities to organize learning environments that are created to strengthen students' 21st-century skills. As such, the teachers' ability to implement and execute the plan are a concern. Thus, the aim of this study is to identify and evaluate preservice teachers' perceptions of their readiness, experiences, and effort in practising STEM education, as well as their degree of confidence in STEM education teaching and learning. A correlational research design was employed in this research to collect data from 113 science-based pre-service teacher trainees in a public university in Malaysia. The participants answered the questionnaire on their perceptions of their experiences and confidence level in learning STEM skills in their university courses and their views towards activities on STEM. Reflecting on the findings, this study has implications for the pre-service teacher trainees (students), faculty and organization as a whole in the preparation towards the execution of STEM in terms of strategies and intervention in school. This is especially advantageous for the university to raise awareness of the benefits of university STEM-related programs to a diverse background of students.

Keywords: Confidence, Preservice Teacher, STEM, Teacher Readiness

1. Introduction

In the 21st century teaching and learning, teaching is getting more challenging and it shows more complexity when the elements of Science, Technology, Engineering, and Mathematics (STEM) are highly and strongly embedded in the courses at the university level. The inclusion of STEM has caused adjustment of the contents and delivery of instruction, which are two major focus areas to produce the end product of the university, the STEM workers. To achieve this aim, the outcomes of a course should include knowledge and skills of STEM such as solving engineering and science problems by applying concepts of science, technology, engineering, and mathematics. Besides, educators or instructors' ability and creativity of instruction contribute to the development of STEM education. For example, they may depend on the advance of technology to have more discussion and create challenging lessons in any form of video presentation to communicate STEM skills. Apart from these, many innovative tools have been introduced, such as a real time simulation software called HOME I/O focusing on the context of a smart house and its surrounding environment with integration of STEM elements (Riera, Emprin, Annebicque, Colas, & Vigario, 2016). School science teachers, who are university graduates, are also STEM workers. Their experience of STEM education at the university is expected to contribute to the teaching and learning in school. Since STEM education is promoted and has become an important part of school teaching and learning, teachers' abilities to sketch and implement the plan have been a concern. Teachers' abilities in guiding students in school should be developed from their teacher training stage. Undergraduate programmes influence much on their future development on how they carry out the lesson plans in school. The overall achievement of STEM acquisition and to what extent the teacher trainees are confident to engage themselves with the skills and knowledge in the teaching and learning is questionable. It was highlighted that university students' perceptions towards STEM curricula and their prospects always provide significant inputs for the STEM development (Basu, 2021). Current studies also focus on university students' ability in STEM (Teoh et al., 2020; Lavi & Dori, 2021).

Thus, this study aims to identify and evaluate preservice teachers' perceptions of their readiness, experiences, and effort in practising STEM education, as well as their degree of confidence in STEM education teaching and learning. This study is guided by the following research questions:

Research Question 1: What are the preservice teachers' perceptions of their readiness, experience, effort, and confidence in STEM practices at their university?
Research Question 2: Are there any relationships between the preservice teachers' perceptions of their readiness, experience, efforts and confidence in learning STEM skills in their university?

2. Literature Review

Science, Technology, Engineering, and Mathematics (STEM) education

STEM represents an acronym of Science, Technology, Engineering and Mathematics and it is a curriculum integrating four specific disciplines such as science, technology, engineering and mathematics. The four disciplines should not be taught as separate and discrete subjects, rather they should be integrated in a cohesive manner based on real-world applications. STEM education started in the 1990s by the US under National Science Foundation (NSF), where engineering and technology with science and mathematics were included in undergraduate and K-12 school education. Since then, STEM education has gained significant interest and recognition by all governments and educators. Related research and publications have also increased tremendously especially since 2010. (Yeping Li et al. 2020).

The Malaysian Education Blueprint (2013-2015) which maps preschool to post-secondary education indicates the importance of STEM education in Shift 1 to "Provide equal access to quality education of an international standard". The transformation of STEM education is expected to occur with a three-wave roadmap (Ministry of Education Malaysia, 2013) as shown in Figure 1. It started in the first wave (2013-2015) with enhancement of the curriculum and provision of proper teacher training in terms of knowledge and skills. It was followed by the second wave (2016-2020) of revising and enhancing the curriculum, increasing public awareness in STEM, and enhancing teachers' various skills and knowledge. In the third wave (2021-2022), the focuses are on various innovations of the skills and knowledge development related to STEM.

Fig.1 The transformation of STEM education (Ministry of Education Malaysia, 2013)

The Government's commitment in encouraging and building STEM talent in the country continues by mainstream and private higher education through establishment of Technical and Vocational Education and Training (TVET) system in 2011. Nevertheless, besides all the effort, there is still a low level of interest in STEM-related studies amongst students when compared to the targeted ratio of 60:40 especially in secondary level. This situation creates a domino effect, with insufficient number of students choosing to pursue STEM studies at the tertiary level (both at universities and technical colleges) and a decline in research and development in STEM if the numbers continue to dwindle at postgraduate levels.

Hence, researchers need to explore what are the possible reasons for poor STEM orientation by looking at the education system including teachers' knowledge, skills and readiness. Academy of Sciences Malaysia (2015) reported ineffective teaching methodology might be one of the reasons. It was found that Malaysia adopts a textbook-based and examination-oriented approach which is believed to have lesser contributions to the development of higher order thinking skills as well as critical and analytical thinking skills.

The Malaysian government has always put efforts to enhance the quality of teachers including pre-service teachers. Continuous professional development has always been a priority for in-service teachers to strengthen their knowledge and skills, upskilling and reskilling align with the new landscape of education. For more promising alignment among the preservice teachers, universities and teacher training institutions are always embracing guidance for sustaining the quality through research. Current research also reported the same concerns. There are some common concerns by teachers in STEM implementation reports such as time constraints, technology competency (Ellis, et. al., 2020) and insufficient understanding about STEM implementation (Ramli & Talib, 2017). Among the barriers highlighted are motivation, long syllabus, time constraint, lack of training and inadequate facilities. Hence, having more comprehensive inputs on how to increase the preservice teachers' potential in STEM development is imperative to driving confidence and making sustained development in education. To gain confidence, researchers have also emphasized some essential aspects, such as innovative methods in promoting STEM (Berisha et al., 2021), STEM content knowledge (Aydin-Gunbatar et al., 2018; Karisan et al., 2019), integrating art into STEM practices (Ramli et al., 2022), as well as letting students experience or engage in STEM activities (Adam et al, 2014; Mat Salleh et al., 2020; Santana et al, 2020).

Conceptual Understanding of STEM Practices

STEM practises are a prominent topic of discussion among educators in Malaysia since they involve complex processes of integrating the four STEM elements. While digital technology is advancing, deep thinking is necessary for innovation. The challenging job of innovative creation of ICT, on the other hand, eases the integration of the other elements in STEM. For this reason, it was highlighted that the integration of technology to assist complicated processes is key to enhancing Science, Technology, Engineering, and Math (STEM) learning (Vahidy, 2018).

Preservice teachers play a critical role in meeting this challenge since they are on the front line of encouraging the younger generation to participate in STEM, as seen in Figure 1. Figure 1 shows a Malaysian STEM development plan. The importance of teachers' roles is emphasised throughout the plan. As a result, instructors play a critical role in bringing the plan to life. Teachers must, in general, take action and fulfil their tasks as outlined in the plan. A strategy that is not carried out may end up being a failure. Hence, preservice teachers, who will be future leaders in the redesigning of STEM lessons, must play a key part in this.

Also, the plan highlights achievement of STEM education in terms of curriculum and courses or practices among institutions and schools. It is clearly stated that STEM practises lay the groundwork for enhancing 21st-century skills (Stehle & Peters-Burton, 2019). This has attracted researchers to investigate educators' understanding of STEM education. Therefore, careful observation of how preservice teachers lead themselves in guiding their students may provide guidelines for STEM practices.

Preservice teachers are the most up-to-date educators, despite the fact that they are labelled as new teachers. In their institutional courses or training, they have learnt a variety of innovative and cutting-edge technology, as well as how to deal with new educational aspects such as 21st-century skills. As a result, preservice teachers are taught to be well-versed in 21st-century STEM techniques. The issue is whether the courses or training they received in their colleges for obtaining experience were sufficient for them to promote STEM practises in their future career in schools. On the other hand, it is learned that experiences are not gained through learning; rather, they are gained through thinking or exerting effort (collaboration and reflection) for improvement when learners reflect and make judgements on their practices (Fazey et al., 2005). Hence, personal factors have also been identified as a major contributor to STEM development. Experiences, on the other hand, can be utilised to guide future STEM practises (Roberts et al., 2018).

Pre-service teachers are encouraged to observe their ability to attain a certain level of achievement when it comes to accomplishments in STEM lessons. A few terminologies are used to characterise how learners assess their accomplishments. "Confidence," "ability," "self-efficacy," and "competence" are some of the terms used (Council, 1994). Their perceived achievement represents their ability to complete a task to the best of their capacity. Because the success of STEM education practises is mainly reliant on self-activities and personal evaluations, this study examined satisfaction with the practises in terms of "confidence." Furthermore, the purpose of the practises is not assigned a specific task or proficiency level, therefore preservice teachers' confidence is assessed to establish their perceived capabilities in STEM practises.

3. Method

Research Design

This study employed a correlational research design to collect quantitative data. This quantitative approach focuses on investigating relationships between variables namely readiness, experience, effort, and confidence.

Sampling

The population of science-based preservice teachers in a public university in Malaysia was 941. In this population, the pre-service teachers engaged in their learning in groups according to their study year and program. Hence, collecting data based on groups provided a better view of their experience towards STEM learning. The population came from four programs with seven to fifteen groups in each program (namely 4 programs x '7 to 15' groups). Hence, there were 37 groups of students in the population. The groups were assigned as clusters in the sampling technique of this study. Each cluster had about 15 to 30 students. A total of 6 clusters, i.e. a sample of 113 participants was randomly selected from the total preservice teacher population.

Instrumentation

The participants answered a questionnaire on their perception in terms of STEM readiness in university courses, experience with STEM, effort, and confidence towards STEM. The questionnaire was constructed following the important aspects highlighted in the transformation of STEM education (Ministry of Education Malaysia, 2013). Overall, they were observed of their readiness in terms of awareness of the university's courses whether they equip preservice teachers' with the appropriate knowledge and skills. Besides, the perceived experience and effort with regards to their planned practice or actions to equip themselves with STEM knowledge and skills via practices along the way to become a teacher. Cronbach's Alpha values for readiness, experience, effort, and confidence are 0.890, 0.836, 0.817, and 0.912 respectively. The items were validated by two experts. The results according to the items are provided in the Appendix.

4. Findings

The findings below are based on the two research questions.

4.1 Finding 1: Preservice teachers' perceptions of readiness, experience, effort, and confidence in STEM education STEM education practices

Table 1 shows the pre-service teachers' perceived levels of readiness, experience, effort, and confidence towards the learning of STEM. The learning of STEM is perceived as a process of gaining knowledge of STEM when they are completing STEM-related courses such as mathematics and science subjects, besides attending STEM-related activities.

Table 1. Descriptive Statistics

	Mean (M)	Std. Deviation(SD)	N
Readiness	4.22	0.63	113
Experience	3.98	0.71	113
Effort	4.34	0.62	113
Confidence	4.07	0.67	113

Their readiness is perceived in terms of knowledge gained in courses which are to be applied in a practicum. The readiness was rated with a mean of 4.22 (SD=0.63). Nevertheless, they rated comparatively lower experience than their readiness in the courses, with a mean of 3.98 (SD = 0.71). Specifically, some interesting findings according to the items were also reviewed to explain the above results. With reference to the Appendix, the result of item 7 "I have the experience of attending STEM activities (eg: Innovation competition)" with mean = 3.93 and SD = 0.95, and item 9 "I am exposed to STEM knowledge in other activities other than in the above courses I've taken (outside of the classroom)" with mean = 3.91 and SD = 0.83 idicate that the pre-service teachers have less experience of attending STEM activities. Even though they had less experience, they put a lot of effort into support the development of STEM education as well as preparing themselves to apply

STEM during their practicum. Their agreement on effort was rated at a mean of 4.34 (SD=0.62). With their effort, experience, and readiness of existing content in the courses, they were confident in applying STEM during their practicum (mean = 4.07, SD= 0.67). Hence, descriptively, the findings depict (Figure 2) a brief structure of their learning at the university. Figure 2 illustrates the pre-service teachers perceived they put some effort into developing their knowledge of STEM, as they agreed that the elements of STEM are embedded in their curriculum. Nevertheless, they found the experience they gained from other activities related to STEM was less. Even though they were less experienced, they responded positively to the level of confidence.

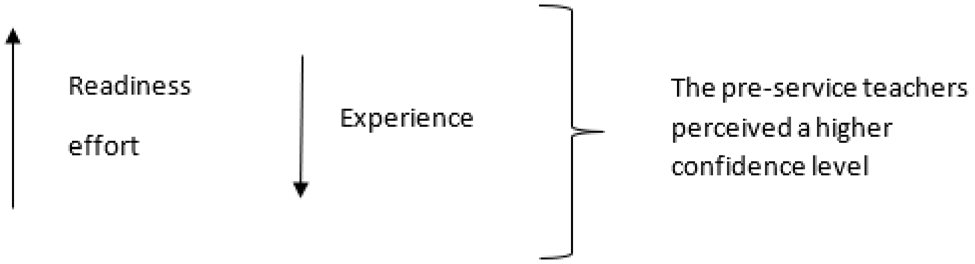

Fig.2 Illustration of Finding 1

4.2 Finding 2: Relationship between readiness, experience, effort and confidence in STEM practices

Findings 2 highlights the perceived confidence and its relationship with readiness, experience, and effort. Table 2 shows the levels of confidence of the respondents in the perceptions of all the aspects in the learning process related to STEM. Based on Finding 1, the following results (as depicted in Table 2) indicate that the confidence level has significant relationships with readiness (0.71, $p<0.05$), experience ($r=0.79$, $p<0.05$), and effort ($r=0.72$, $p<0.05$). The results show all the factors such as readiness, experience, and effort significantly related to the confidence level. These factors are essential in ensuring the acquisition of knowledge in STEM. Interestingly, the result shows the highest correlation between experience and confidence level.

Table 2. Correlations

		Confidence
Readiness	Pearson Correlation	0.711**
	Sig. (2-tailed)	<0.001
	N	113
Experience	Pearson Correlation	0.790**
	Sig. (2-tailed)	<0.001
	N	113
Effort	Pearson Correlation	0.718**
	Sig. (2-tailed)	<0.001
	N	113

5. Discussion

This study revealed that the pre-service teachers perceived they have to put some effort into developing their knowledge of STEM within their university study structure. They also rated well for the content readiness in university as they agreed that the elements of STEM are embedded in their curriculum. The importance of STEM aspects in the curriculum had been highlighted in previous findings. Through course participation, pre-service teachers' awareness and intentions towards STEM practises might be influenced. (Karisan et al., 2019; Aydin-Gunbatar et al., 2018).

Nevertheless, the pre-service teachers found the experience they gained from other activities related to STEM were lesser. Even though they were less experienced, they responded positively to the level of confidence. They were confident in their practises because they respected STEM practises in their own unique ways. Their efforts were visible in the work they produced. For instance, introducing art into STEM activities could be an example of an endeavour to incorporate STEM with practises (Ramli et al., 2022). The experience is exceptionally essential since the result also shows that there is a relationship between experience and confidence.

More activities are required to be organized in university. Learners' engagement in the learning activities is crucial. Their engagement in any exposure related to STEM may provide impact for their STEM skills enhancement. Highly engaging learners in STEM activities is a good way to increase their confidence (Heron, & Williams, 2022). It was revealed in previous study that STEM skills are not depending on formal learning courses in institution but also informal activities such as project activities which will in return get them highly engaged in STEM activities if they intend to participate (Adam et al, 2014; Santana et al, 2020). Previous reports and studies also indicated that undergraduates benefited from research-based activities in universities (Boyer Commission, 2003; Kuh, 2008). They require additional exposure to be able to connect their STEM skills to their learning materials. Also, the exposure provides opportunities for them to do more reflection and hence increases positive experience in STEM practices. It also offers pre-service teachers to provide more guidance in the mentor mentee program as mentioned in Figure 1 (Ministry of Education Malaysia, 2013). More importantly, the activities promise to build up a positive attitude and hence improve academic progress and, as a result, increase their confidence (Teoh et al., 2020).

The efforts to improve pre-service teachers' or undergraduates' skills in STEM are numerous. Outputs of these special programs or instructions have been a contributing factor in STEM development (Manduca et al., 2017). It was also informed that undergraduates gain more knowledge on the field in which they develop 21st century skills namely critical thinking and communication skills, networking opportunities, and likelihood to become STEM educators, i.e. STEM workers (Hathaway et al., 2002). Programs for pre-service teachers are always getting a lot of attention. More elements of STEM such as critical thinking skills are highly implemented and practiced among students in universities. Even though STEM elements are embedded or directly included in most of the programs in universities, monitoring students' improvement of STEM skills remains a challenge. The confidence level provides a direction on their plans and ability to conduct lessons with STEM elements in schools or other institutions. According to the findings of this study, students require more experience to gain confidence in guiding the next generation through school activities. All parties benefit from the activities, which support and respond to the growing STEM activities (Solanki et al., 2019).

6. Conclusion

This study indicated that pre-service teachers' confidence in STEM practises was highly associated to experience, even though the level of experience was rated lower when compared to readiness and effort. On the other hand, more effort needs to be contributed while experiencing any activity.

7. Co-Author Contribution

The authors affirmed that there is no conflict of interest in this article. The first author carried out the overall plan for the writing and contributed to the findings and discussion, the second author edited the manuscript, the third author contributed to the writing of literature review, the forth author wrote research methodology, and the fifth author made an overall checking.

8. Acknowledgements

This study is part of a larger study supported by the Special Research Grant (Geran Penyelidikan Khas) from Universiti Teknologi MARA (UiTM). Grant: 600-RMC/GPK5/3 (040/2020).

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Appendix

Items

	N	Mean	Std. Deviation
STEM readiness in a course (equip with STEM knowledge embedded in the course)			
1. **STEM education** (programs, courses or certification) has been introduced in my university courses.	113	4.31	0.695
2. Many of courses I took contain **elements of STEM**	113	4.28	0.750
3. There are differences in coursework and instruction in the **STEM courses** as opposed to non-STEM courses.	113	4.12	0.741
4. STEM elements have been **integrated** as something other than merely adding more topics of science and mathematics into my courses in university.	113	4.18	0.735
5. I am aware of the importance of **integrating STEM** in all the subjects I took (outside of the classroom) during p**racticum.**	113	4.32	0.672
Experience (exposure)			
6. I am well exposed to STEM education at my university.	113	4.05	0.789
7. I have the experience of attending STEM activities (eg: Innovation competition).	113	3.93	0.952
8. My lecturers (who apply STEM) influence my application of STEM in my teaching practicum	113	4.04	0.876
9. I am exposed to STEM knowledge in other activities other than in the above courses I've taken (outside of the classroom).	113	3.91	0.830
Confidence			
10. I have the confidence to apply STEM in my **practicum**.	113	4.03	0.750
11. I will apply STEM in my **practicum.**	113	4.27	0.707

12. My confidence level on how to conduct STEM education is high.	113	3.94	0.805
13. I am confident to introduce STEM education to my friends or community.	113	4.04	0.767
Effort			
14. I will put a lot of effort to support the development of STEM education.	113	4.35	0.665
15. I need to prepare myself to apply STEM in my practicum.	113	4.35	0.691
Valid N (listwise)	113		