Enhancing Prospectives Educators' Readiness Through Multidisciplinary Collaboration in STEM Education: An Analysis of Students Enrolled in Science and Mathematics Majors at a Public University in Malaysia

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Abstract: Introducing successful STEM education in Malaysian educational institutions can aid in cultivating critical thinking skills among prospective educators, as STEM education is a pathway to acquiring 21st-century skills. By incorporating STEM courses into the curriculum through collaboration with industries, it helps to equip future teachers with the skills necessary to thrive and adapt in the evolving technological world. Aligned with the evolving landscape, this study aims to assess the readiness of future science and mathematics educators for STEM education. The key areas under examination encompass prospective teachers' individual teaching confidence and beliefs, expectations related to teaching outcomes, and attitudes toward 21st-century learning. These aspects will be measured across two distinct programs. This study involved 140 students majoring in Science and Mathematics and took STEM course from a faculty of education at a public higher institution in Malaysia. The participants have taken part in training sessions, including courses on the Internet of Things (IoT), hands-on educational tools, and Solar Energy, conducted in collaboration with STEM experts. The findings indicated a high level of personal teaching efficacy and belief, teaching outcome and expectancy beliefs, as well as 21st Century learning attitudes among prospective science and mathematics teachers. Therefore, engaging STEM experts and implementing a multidisciplinary teaching approach in STEM courses can enhance prospectives educators' confidence and comprehension of STEM teaching.

Keywords: STEM Education, Collaborative Teaching, Prospectives Educators, Multidisciplinary Collaboration

1. Introduction

Over the last few decades, the fields of Science, Technology, Engineering, and Mathematics (STEM) have consistently served as a crucial worldwide foundation for preparing the upcoming workforce. These subjects aim to equip the next generation with the skills needed to address contemporary challenges in areas such as the economy, technology, education, and the evolving skill set required for the 21st-century workforce. There has been an increased effort in several countries to strive to produce STEM talent to meet future economic markets. As of August 2023, there was an increase in student enrollment in Science, Technology, Engineering, and Mathematics (STEM) education, reaching 45.73 percent (New Straits Times, 2023). Thus, Malaysia is also consistently working to develop knowledgeable and skilled human capital to engage in the fields of STEM. However, there have been several concerns identified on the ability of teachers to be able to integrate STEM into their curriculum and into their learning (Diana, 2021). Many researchers suggested that the main problem in STEM education lies in the low level of competency among STEM teachers (Margot & Kettler, 2019 ; Kurup et al., 2019; Nasri et al., 2020). Since STEM practices are new knowledge to trainee teachers and is a current trend to be focused on education, trainee teachers' efforts and willingness to be involved in STEM practices is highly recognised as a factor to build their readiness and confidence in STEM practices (Boset & Asmawi, 2020; Muhammad and Noor Ibrahim, 2022). It has also been noted that teachers who are teaching subjects in STEM need to adopt a positive approach to STEM by learning from other subjects taught by other teachers. Therefore, preparing for future educators through multidisciplinary collaboration in STEM education is essential for teaching STEM to educate and prepare a holistic future generation. Collaborative teaching allows all future STEM teachers to have a direct consultation with the experts throughout the project, whereby the consultation could develop responsive and responsible beliefs among future teachers (Mohamed, Rasid, Ibrahim & Seshaiyer (2023).

In addition to STEM, there is a significant demand in our current data-driven society to equip the upcoming STEM workforce in problem-solving that prioritizes a human-centered approach. This is to achieve balance between boosting the economy and addressing societal challenges through an integrated infrastructure that encompasses advanced technologies, physical environments, and service platforms. Furthermore, as information technology increasingly intertwines with daily life, society becomes tightly integrated, especially as the industrial world becomes more virtually interconnected.

Thus, where digital plays an important role in sustainable and economic development, the need to construct IoT systems, analyze big data, and predict with AI are becoming a norm. Teachers from STEM disciplines help to not just build technical skills and content knowledge but also help to promote interdisciplinary problem solving, enhance 21st century skills and support digital literacy to solve real-world challenges (Seshaiyer, 2021).

Despite having scientific and mathematical elements, most STEM activities mainly rely on 21st century skills (Koh & Tan, 2021). The basis for enhancing 21st-century abilities is laid through STEM practices (Stehle & Peter-Burton, 2019). Interaction with peers is a social skill acquisition process for the recognition of 21st century skills to work collaboratively. Trainee teachers need more guidance on practicing the STEM approaches, working collaboratively has been identified as a way for them to develop STEM (Floden et al., 2020; Tambunan & Yang, 2020; Mohamed et al., 2023). They also need to understand how to employ novel educational frameworks that provide the opportunity for STEM educators to not only engage students through effective tools to represent, understand and solve real-world problems but also engage them in using tools to decide, predict or solve a real-world problem (Seshaiyer, 2021). Since STEM typically incorporates instructional practices, such as problem-based learning, project-based learning, or inquiry-based learning, that can be challenging for teachers and educators to implement, as they require teachers and educators to move away from direct instruction and towards a facilitator role supporting student-led exploration (Boice et al., 2021).

Multidisciplinary STEM collaborations that signify a good, unified system has many advantages of facilitating cooperation. Integrating STEM is a collective effort where educators and external experts particularly from the industries should collaborate and help each other to educate and improve STEM learning for students. The students are to take advantage of the opportunities provided by the educators and industry experts where they can receive hands-on training with mentors and adapt to their learning to implement a STEM project. Thus, interaction should be fostered at different levels to make necessary improvements and to solve any problem that may arise during the implementation of a STEM project by learners cordially to achieve and maximize the output (Wang et al., 2020). With recent advances in technology, many STEM activities have been created to promote trainee teachers' understanding of the integrated nature of STEM (VanDerHeide & Marciano, 2022). Hence, higher education needs to prepare future teachers to be able to engage and teach students through effective STEM instruction that integrates such emerging technologies which brings us to the focus of this work (Al-Imran & Al-Kabi, 2020).

It is reported that there are various issues and challenges in implementing STEM. These include the teachers' lack of confidence in explaining STEM applications to the students (Margot & Kettler, 2019; Kelley et al., 2020), teachers' insufficient understanding of STEM pedagogy, and lack of STEM implementation expertise (Dong et al., 2020; Jekri & Han, 2020). Diana and Kamisah (2018) also found that the adoption of 21st-century learning approach in the integrated STEM was minimal due to the lack of understanding about the method. There were also issues such as teachers' resistance to adopting new teaching methods in STEM and insufficient support in teaching methods, facilities and professional development training related to STEM (Ismail et al., 2019; Diana, 2021). From the Malaysian perspective, studies conducted found that the implementations of STEM teaching among teachers are not comprehensive inconsistent and have not developed to an acceptable degree (Diana & Kamisah, 2018; Mahmud et al., 2019). The teachers were also reported to have inadequate knowledge of STEM topics. These findings revealed that teachers lacked the expertise and positive mindset necessary to implement the teaching and learning approach. Therefore, more efforts should be made to deal with these issues and challenges to ensure that teachers are provided with sufficient support to increase their motivation and self-confidence (Margot & Kettler, 2019).

The purpose of this study is to understand the disposition and preparedness levels of future science and mathematics educators at a major public institution in Malaysia, for STEM education in Society 5.0. In particular, we consider three items including personal teaching efficacy and beliefs; teaching outcome and expectancy beliefs and; 21st Century learning attitudes. The objectives of this study are as the following:

1. To determine the level of science and mathematics prospectives educators' personal teaching efficacy and beliefs, teaching outcome and expectancy beliefs, and 21st Century learning attitudes.
2. To determine the significant differences in the mean score of prospectives educators' personal teaching efficacy and beliefs, teaching outcome and expectancy beliefs, and 21st Century learning attitudes between majors.

The outline of the paper is as follows. In section 2, we describe the overall vision of this project conducted at a major public institution in Malaysia along with the description of a particular integrated STEM course that this research is built on. Section 3 introduces the methodology employed to collect the data and the associated research instruments used to validate and interpret findings from the data. Section 4 presents the results and discussion. Lastly, conclusions are presented in Section 5.

2. Overview of Integrated STEM Learning at UiTM

Aligned with the university's vision to establish UiTM as a globally renowned institution in science, technology, humanities, and entrepreneurship, the concept of STEM education serves to foster these interdisciplinary links. This involves merging teaching expertise and content knowledge through collaborations with various organizations or industries (Gillen et al., 2021). The university's values of pursuing excellence, fostering synergy for industry and societal benefit, and upholding integrity align well with the introduction of STEM Education at the Faculty of Education. The motto of unlocking potentials and shaping the future resonates with the philosophy that knowledge transfer enables individual excellence. Consequently, STEM education was integrated into the curriculum for Science and Mathematics majors at UiTM's Faculty of Education in 2021. The course aims to equip students with the ability to apply mathematical and pedagogical knowledge in teaching science and mathematics, fostering an interdisciplinary approach. It involves developing critical analysis of STEM lessons for diverse student needs, planning integrated STEM instruction, and creating instructional materials. Through lectures, seminars, and collaboration with industries, students engage in problem-based and project-based learning, designing their STEM activities.

The Inquiry and Problem-Based Learning approach during the 14 weeks of classes particularly during the engagements with industries means student-centered teaching pedagogies that encourage active learning and critical thinking through investigation are highly implemented. This model is embedded to encourage student-centered teaching pedagogies towards active learning and critical thinking through investigation. For example, the first project was on Green Energy Solar Panel. Through building solar boats, students were able to analyze and evaluate their end products, which promotes critical thinking and problem-solving during presentations and Question and Answer sessions with the industry involved. The ideas are not only about the solar which powered the boat but also taking into consideration the design, the speed and the boat motion in a straight line. Internet of Things (IoT) was delivered by instructors from the University Centre for Innovative Delivery and Learning Development (CIDL). Finally, a collaborator from a company that works closely with the global brand LEGO® Education provided training and hands-on learning through effective educational tools.

Implementing effective STEM education demands interdisciplinary collaboration among educators. Prior math and science knowledge is crucial for grasping real-world STEM applications. Science students from varied majors (Physics, Chemistry & Biology) blend scientific expertise with engineering and tech concepts via STEM education. Figure 1 depicts overlapping Science and Math courses, reinforcing shared subject matter. Alongside these courses, students undertake common educational coursework. A meticulous curriculum and instructions facilitate linking new information with prior knowledge, aiding students during industry-involved project assessments. This showcases explicit learning within the integrated STEM approach.

Implicitly, the STEM education course was delivered through lectures. The lecturers from the faculty cover the introductory part on the definition, theories, framework, and the purpose of integrating Science, Technology, Engineering and Mathematics (STEM) disciplines in teaching and learning. Subsequently, the industry's involvement starts under the topic of *Designing Integrated STEM Instruction and Instructional Materials*, which also include workshops and seminars during the final weeks.

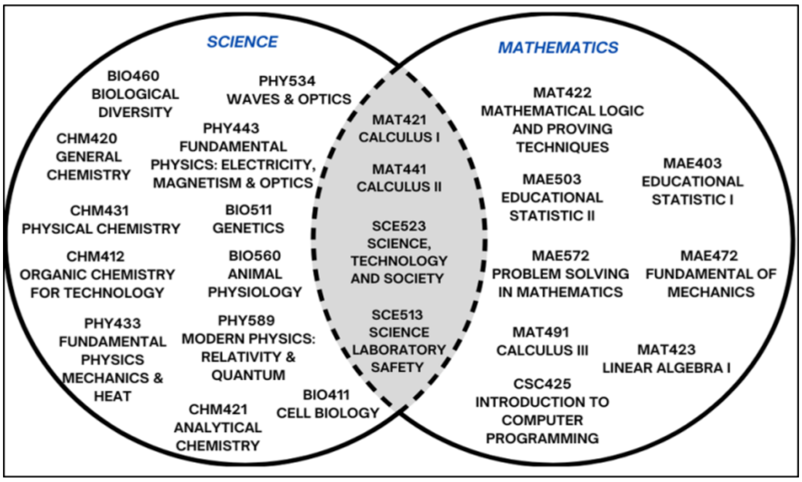

Fig. 1 Venn Diagram of common educational coursework learning within the integrated STEM approach for Science and Mathematics programs in Faculty of Education, UiTM

3. Research Methodology

This study employed a quantitative method using a descriptive research design via a set of questionnaires. The participants consisted of 140 respondents from Science and Mathematics trainee teachers from a public higher institution in Malaysia. They were from four different majors (Biology, Chemistry, Physics, and Mathematics) who had attended courses like Internet of Things (IoT) and Solar Energy conducted collaboratively with experts. The data is collected from the 140 respondents who were enrolled in semester 5 sciences and mathematics in March – July 2022 session. The questionnaire consisted of three sections: Personal Teaching Efficacy and Beliefs (11 items); Teaching Outcome and Expectancy Beliefs (9 items) and 21st Century Learning Attitudes (11 items). The survey was based on the science teacher efficacy belief instrument scale by Riggs and Enochs (1990), which was used to measure outcome expectancies among science teachers. All the items had responses on the scale varying from 1 (strongly disagree) to 5 (strongly agree). The reliability of the analysis for the instruments includes Cronbach's alpha score of Personal Teaching Efficacy and Beliefs (0.903); Teaching Outcome and Expectancy Beliefs (0.881) and; 21st Century Learning Attitudes (0.902). Descriptive statistic (Mean scores, standard deviation) and inferential statistic (Independent sample t-test) were used to determine the research objectives.

4. Results and Discussion

This section reports the analysis results of the data gathered from the respondents of the study. The report starts with the demographic background of the respondents followed by the analysis data based on the research objectives. The results' discussion will be presented in each subsection reporting the data.

4.1. Demographic Background of the Respondents

Table 1 shows that a total of 140 students have responded to the questionnaire. Female students formed the majority of the respondents (n=112, 80.0%) while male students contributed to only 20% (n=28) out of the total number of respondents. Table 1 further portrayed the background of the program of the respondents, and it indicated that most of the respondents were from science program (n= 78, 55.7%) as compared to respondents from Mathematics program (n= 62, 44.3%). Apart from that the analysis of STEM knowledge before attending workshops in the SME543 course also reported in this study.

Table 1. Distribution of respondents according to demographic background

Gender	Frequency	Percent (%)
Female	112	80.0
Male	28	20.0
Total	140	100
Program	Frequency	Percent
Science	78	55.7
Mathematics	62	44.3
Total	140	100

As seen in Table 2 below, STEM knowledge of the respondents before attended workshops in SME543 course were at beginner level (n=88, 62.9%), followed by respondents who have no STEM knowledge (n=46, 32.9%), Intermediate level in STEM knowledge (n=5, 3.6%), and only 0.7% (n=1) of the respondents claimed themselves to be at advanced level in STEM knowledge. Most students claimed to have some knowledge on STEM education before they actually embarked on the course. This is possible since the students have basic science knowledge from schools, and courses taken at pre-university and at previous semesters at the bachelor's degree level. For example, subjects like Nature of Science, Problem Solving in Science, Science Technology & Society, Science Laboratory

Safety, Fundamental Physics: Electricity, Magnetism and Optics among others, along with educational courses like Innovative Technologies in Teaching and Learning, and Curriculum and Instruction have helped them to be familiar with the components in STEM education.

Table 2. Distribution of respondents according to demographic background

STEM Knowledge before attended workshops in SME543 course	Frequency	Percent
Advanced	1	0.7
Beginner	88	62.9
Intermediate	5	3.6
None	46	32.9
Total	140	100

4.2. Level of Science and Mathematics Trainee Teachers' Personal Teaching Efficacy and Beliefs, Teaching outcome and Expectancy Beliefs, and 21st Century Learning Attitudes

The overall mean scores and standard deviation for the three aspects of future STEM teachers in Table 3 show that the respondents have a high level of personal teaching efficacy and beliefs (M= 4.03), teaching outcome and expectancy beliefs (M=4.18), and 21st Century learning attitudes (M= 4.40). Among the three aspects, "21st century learning attitude" has the highest-level while "Personal Teaching Efficacy and Beliefs" showed the lowest level among the trainee teachers in preparing them through multidisciplinary collaboration in the STEM course. This means that an integrated STEM course taken by the students has provided them with necessary knowledge and skills fulfilling the aspects that are important as future STEM teachers. The subsequent Tables 3.2a, 3.2b and 3.2c present the detailed data analysed from each item in all aspects accordingly.

Table 3. The overall mean score of three aspects of future STEM teachers

Aspects of Future STEM Teachers	Overall Mean Score	Standard Deviation
Personal Teaching Efficacy and Beliefs	4.03	.68
Teaching Outcome and Expectancy Beliefs	4.18	.72
21st Century Learning Attitudes	4.40	.63

Table 3a shows the mean score of all the 11 items in personal teaching efficacy and beliefs aspect. Out of the 11 items, 4 items were rated at the moderately high level with mean scores (3.5>M>4.0). Item 1, "I am continually improving my science/math teaching practice" received the highest rating (M=4.24) while item 8 "I am confident that I can answer students' science/math questions" fared the lowest (M=3.86). Given most of the items fared at the high level, the data shows that the integrated STEM course has given the students the opportunity to enhance their personal teaching efficacy and belief as future STEM teachers. Particularly, the trainee teachers see the importance of reflecting and keep improving on their teaching practices, they are highly aware of the important steps to teach science/math effectively, and highly confident that they would be able to teach effectively. However, the level was not consistent on some other aspects like their belief in their skills (M=3.89) and understanding of science concepts (M=3.99). Likewise, the trainee teachers fared themselves moderately high on helping students who struggled in understanding concepts (M=3.98) and on their confidence to answer students' questions as reported earlier.

Table 3b shows the mean scores of the 7 items (12 - 18) in the teaching outcome and expectancy beliefs section. All the items received high rating (M>4) with item 13 "The inadequacy of a student's STEM background can be overcome by good teaching" rated the highest (M=4.31). This indicates that the trainee teachers understood that teaching practices adopted by teachers have a great impact on students' performance. Consistently, item 14 "When a student's learning in STEM is greater than expected, it is most often due to the trainer/facilitator having found a more effective teaching approach" was highly fared by the respondents with M=4.29. However, item 16 "If students' learning in STEM is less than expected, it is most likely due to ineffective STEM teaching" describing a contrast statement in item 14 that received least agreement from the trainee teachers (M=4.01). Likewise, item 18 "Minimal student learning in STEM can generally be attributed to their teacher/trainer" received a similar rating level with M=4.06; barely passed the 'agree' indicator. This inconsistency could be attributed to the negative connotation entailed in item 16 and 18, such as 'students' learning in STEM is less than expected' and 'minimal student learning in STEM' impacted by teachers or their ineffective teaching practices.

From Table 3c, we note that the respondents agreed that the importance of skills such as "Include others' perspectives when making decisions" (M=4.48), "Manage their time wisely when working on their own" (M=4.44)" and "Respect the differences of my peers" (M=4.44) item is suggested to be the contributor to the highest mean scores in the "21st century learning attitude". Additionally, the high rating given by the respondents for all items in this aspect show that they perceived themselves to have a high level of critical thinking, collaborative, creativity and communication skills (4Cs), which among the essential skills need to be possessed by the 21st century learners. The high means scores obtained for all items also could be due to the SME543 course nature that emphasizes the '4Cs' through the classroom implementation, activities, and assignments that need to be completed by the students. Moreover, the course adopted a multidisciplinary approach requiring students to apply and integrate their prior knowledge with knowledge of different disciplines acquired from the course and interact with peers and collaborators aside from their course instructor. In tandem, the results of this study validated Koh and Tan's (2021) assertion that most STEM activities mainly rely on 21st century skills and STEM itself could be the best platform to enhance the 21st century skills (Stehle & Peters-Burton, 2019). As such, the trainee teachers in this study have benefitted greatly from the STEM course, particularly in enhancing their 21st century skills.

Table 3a. The overall mean score of respondents' personal teaching efficacy and belief

Items	N	Mean	Std. Deviation
1. I am continually improving my science/math teaching practice.	140	4.24	.61
2. I know the steps necessary to teach science/math effectively.	140	4.05	.60
3. I am confident that I can explain to students why science experiments work.	140	4.05	.64
4. I am confident that I can teach science/math effectively.	140	4.01	.62
5. I wonder if I have the necessary skills to teach science/math	140	3.89	.80
6. I understand science concepts well enough to be effective in teaching science/math.	140	3.99	.70
7. Given a choice, I would invite a colleague to evaluate my science/math teaching.	140	4.07	.71
8. I am confident that I can answer students' science/math questions.	140	3.86	.73
9. When a student has difficulty understanding a science/math concept, I am confident that I know how to help the student understand it better.	140	3.98	.68
10. When teaching science/math, I am confident enough to welcome student questions.	140	4.05	.65
11. I know what to do to increase student interest in science/math.	140	4.09	.72
Overall mean score		4.03	.68

Table 3b. The overall mean score of respondents' teaching outcome and expectancy beliefs

Items	N	Mean	Std. Deviation
12. When a student does better than usual in STEM, it is often because the trainer/facilitator exerted a little extra effort.	140	4.19	.71
13. The inadequacy of a student's STEM background can be overcome by good teaching.	140	4.31	.66
14. When a student's learning in STEM is greater than expected, it is most often due to the trainer/facilitator having found a more effective teaching approach.	140	4.29	.69
15. The trainer/facilitator is generally responsible for students' learning in STEM.	140	4.25	.71
16. If students' learning in STEM is less than expected, it is most likely due to ineffective STEM teaching.	140	4.01	.84
17. Students' learning in STEM is directly related to their trainer's/facilitator's effectiveness in STEM teaching.	140	4.16	.69
18. Minimal student learning in STEM can generally be attributed to their teacher/trainer.	140	4.06	.72
Overall mean score		4.18	.72

Table 3c. The overall mean score of respondents' 21st Century learning attitudes

Items	N	Mean	Std. Deviation
19. Lead others to accomplish goals.	140	4.29	.66
20. Encourage others to do their best.	140	4.39	.66
21. Produce high quality work.	140	4.38	.66
22. Respect the differences of my peers.	140	4.44	.59
23. Help my peers.	140	4.42	.61
24. Include others' perspectives when making decisions.	140	4.48	.62
25. Make changes when things do not go as planned.	140	4.39	.60
26. Set our own learning goals.	140	4.40	.61
27. Manage our time wisely when working on our own.	140	4.44	.61
28. Choose which assignment out of many needs to be done first.	140	4.36	.72
29. Work well with students from different backgrounds.	140	4.41	.62
Overall mean score		4.40	.63

Teaching efficacy and outcome expectancy belief are important aspects in shaping teacher's self-trust on their ability to conduct teaching and learning effectively and the self-evaluation of a teacher related to his/her knowledge, skills, and abilities related to teaching (Sadaf & Gezer, 2020; Kareem et al., 2022). As such, Shahat et al., (2022) in their study found that STEM trainee teachers who believed themselves to be highly successful in their teaching. The outcome of their study also showed that the trainee teachers had higher perceptions of themselves regarding personal self-efficacy beliefs and outcome expectations for science teaching which are very much in-line with the findings of this study (Shahat et al., 2022). Through the exposure that the trainee teachers received from the SME543 course, they highly perceived their confidence in teaching STEM related content and understanding of how teaching practices affect students' learning.

As mentioned earlier, the multidisciplinary approach, collaborative teaching and nature of the course itself have provided the trainee teachers with ample opportunities to experience circumstances such as, working on group projects and hands-on activities guided and evaluated by STEM practitioners; could elevate their teaching efficacy and outcome expectancy as future STEM teachers. Evidently, a study by Salleh et al., (2020) reported that STEM trainee teachers who provided with opportunity to practice their knowledge in authentic experience, collaborating with others and engage in reflective practice developed more confidence in their teaching abilities and be able to identify effective strategies that help them to deliver STEM content in more effective.

Thus, providing trainee teachers with a high level of efficacy is really important as they could help their students in future to achieve, and encourage them to take responsibility for their learning (Kareem et al., 2022; Orakcı et al., 2023). The higher efficacy and belief of a mathematics or science teachers have the higher tendency for the teachers to accept and value students' suggestions, ideas, and judgements and as a result, students' achievement, motivation, performance, and self-efficacy beliefs related to STEM-related subjects increase (Kelley et al., 2020).

As highlighted, teaching practices adopted by teachers have a great impact on student's performance. By having effective teaching approaches and improving instructional strategies, teaching performance and motivation may help their future students to feel more confident in class (Catalano et al., 2019; Buechel, 2021; Arslantas, 2021). Improving skills and teaching performance during teachers' training promotes associational, divergent, and creative thinking which are essential of thinking skills in 21st-century learning attitudes (Allen & Toth-Cohen, 2019), which means, future educators may feel more enthusiastic and take responsibility for their learning.

4.3. Significant Differences in the Mean Score of Trainee Teachers' Personal Teaching Efficacy and Beliefs, Teaching Outcome and Expectancy Beliefs, and 21st Century Learning Attitudes between Majors

Table 4a demonstrates program differences in trainee teachers' efficacy beliefs, teaching outcome and expectancy beliefs and 21st Century learning attitudes. As shown in the table, Mathematics trainee teachers had higher mean scores (M= 4.10, SD=.46) in teachers' efficacy beliefs and 21st Century learning attitudes (M= 4.44, SD=.51) aspects as compared to those of trainee teachers from a science program.

Table 4a. The mean scores between Science and Mathematics programs for three aspects

Aspects	Program	N	Mean	Std. Deviation
Personal Teaching Efficacy and Beliefs	Science	78	4.00	0.54
	Mathematics	62	4.10	0.46
Teaching Outcome and Expectancy Beliefs	Science	78	4.16	0.60
	Mathematics	62	4.16	0.57
21^{st} Century Learning Attitudes	Science	78	4.37	0.56
	Mathematics	62	4.44	0.51

Additionally, independent sample t-test analysis as shown in Table 4b was used to confirm whether it leads to significant differences of all the three aspects between the two programs. However, the analysis shows that there were no statistically significant differences in the mean scores of the three aspects (personal teaching efficacy and beliefs, teaching outcome and expectancy beliefs and 21st-century learning attitudes) between programs since $p > .05$. In other words, Mathematics trainee teachers had the same efficacy beliefs, teaching outcome and 21st Century learning attitudes as those of Science trainee teachers.

Table 4b. Independent Sample T-test between Science and Mathematics for three aspects

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Personal Teaching Efficacy and Beliefs	Equal variances assumed	0.551	0.459	-1.138	138	0.257	-0.098	0.086	-0.268	0.072
Teaching Outcome and Expectancy Beliefs	Equal variances assumed	0.052	0.819	0.011	138	0.991	0.001	0.099	-0.196	0.198
21st Century Learning Attitudes	Equal variances assumed	0.688	0.408	0.765	138	0.446	-0.070	0.092	-0.251	0.111

Past studies showed mixed findings on the influence of teachers' educational background, school level, qualification, seniority or program major on teachers' teaching efficacy and outcome expectancy beliefs. For instance, Orakcı (2023), in their study involving 379 teachers in Turkey public schools in the 2021- 2022 academic year as samples, showed no statistical differences in teachers' self-efficacy beliefs between gender and school level. However, the teachers' seniority and education level created a significant difference in their self-efficacy beliefs. In tandem, Shahat (2022) found that trainee teachers from different majors have no effect on their self-efficacy beliefs and teaching outcome expectancy beliefs, which are in line with the findings of this study involving trainee teachers from Science and Mathematics programs. In contrast, a study found that program majors significantly influenced self-efficacy, revealing a statistical difference between students with different majors (2020). Similarly, a study by Shaukat et al., (2020) found that teachers' qualifications played a significant role and impacted teachers' efficacy and outcome expectancy beliefs. In this view, Orakcı (2023) argued that the increase in seniority and the level of education, the knowledge in the field deepens and affects teachers' self-efficacy beliefs positively. With increasing complexity, teachers' confidence in delivery and ensuring students' effective learning In the context of this study, most of the trainee teachers rated themselves with a lack of STEM knowledge prior to learning the SME543 course, indicating that the course significantly influenced how they perceived their teaching efficacy, outcome expectancies beliefs, and 21st Century learning attitudes.

5. Conclusion

It was found that the level of Science and Mathematics trainee teachers' personal teaching efficacy and beliefs, teaching outcome and expectancy beliefs, and 21st Century learning attitudes were relatively good as perceived by them in both programs after completing SME543, an Integrated STEM education course. The collaboration with various industries seemed to play an important role in interdisciplinary activities conducted in the course. It holds several implications for the education system, teaching practices, and student learning outcome. Among others, multidisciplinary collaboration allows future teachers to develop a comprehensive understanding of STEM subjects by integrating concepts from multiple disciplines. This integration fosters interdisciplinary learning experiences and develop a holistic understanding of the world. It also encourages future teachers to explore innovative teaching strategies and instructional methods through incorporate hands-on activities, project-based learning, inquiry-based approaches, and technology-enhanced instruction to engage students and promote active learning in STEM subjects. All these efforts in STEM instruction are aligned with the development of 21st-century skills such as creativity, innovation, adaptability, and digital literacy. Thus, preparing future teachers for the demands of the modern workforce and society.

To conclude, enhancing future teachers' readiness through multidisciplinary collaboration in STEM are crucial for understanding how these traits can be cultivated and how teacher training institutions can consistently support and enhance the quality of future teachers.

5. Suggestions for further research

For future research endeavors, it is advisable to replicate the study on a larger sample size, establishing correlations with different variables to obtain more detailed results. In addition, it is suggested for similar research to investigate the sustained effects of the SME543 Integrated STEM education course on science and mathematics trainee teachers by assessing how the enhanced self-efficacy, beliefs, and 21st-century learning attitudes evolve and influence teaching practices in the long run. Additionally, researchers also can explore the strategies and methodologies adopted by trainee teachers in the classroom after undergoing STEM education. This shift in direction, along with new objectives and methodologies, promises to yield a more comprehensive understanding of the prolonged effects of STEM education on trainee teachers, providing valuable insights for the improvement of teacher training programs.

6. Co-Author Contribution

The authors stated that there are no conflicts of interest in this article. The primary author executed the comprehensive writing plan, contributed to the findings and discussion, the second author formulated the research methodology and serves as the corresponding author, the third and fourth authors revised the manuscript and reviewed grammatical errors, the fifth and sixth authors handled data entry, the seventh and the last authors conducted an overall review.

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8. References

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