Current Situation and Analysis of STEM Education Competencies of Education Majors

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Abstract. In recent years, STEM education has become a common concern in international education reform and research as a method of teaching that requires teachers to help students integrate science, technology, engineering and mathematics into real-world problem-solving. STEM teaching has gradually entered primary and secondary education classrooms. However, the STEM education capacity of primary and secondary schools is currently weak, the teachers are inadequate, and the STEM education capacity of teachers directly affects the learning outcomes of students. This study used a questionnaire to investigate the current STEM education competencies of education majors. As far as the results are concerned, they reflect that the STEM education concept is widely recognised, and the current status of education majors' overall STEM education competency is at an intermediate level. Therefore, this study expects the future instructional design to emphasise disciplinary integration, pay attention to the gender ratio of the education profession, and use technology tools to assist STEM teaching.

1. Introduction

STEM is an umbrella term used to combine the different but related technical disciplines of science, technology, engineering, and mathematics (2017). STEM education is a complex mechanical addition of disciplines. However, it is an organism in which the disciplines are fully integrated. The purpose of STEM education is to cultivate students' comprehensive qualities and their ability to apply interdisciplinary knowledge to solve real-world problems and improve, as well as improve their international competitiveness in the future. STEM education is designed to develop students' comprehensive qualities and ability to apply interdisciplinary knowledge to solve practical problems.

The current trend in international STEM education has gradually moved from theory to practice. For students, many skills cannot be learned through disciplinary knowledge alone; disciplinary knowledge is the foundation, while STEM education develops students' problem-solving, critical thinking, creativity, and leadership skills through a gradual approach. In this context, teachers' STEM education competency directly affects the effectiveness of STEM education, which puts a higher demand on their competency level. Therefore, teachers should integrate STEM teaching concepts into their daily teaching. In addition to having solid language skills and relevant expertise in early childhood pedagogy, teachers should also have a reserve of STEM interdisciplinary knowledge to guide students to think about and solve practical problems in the target language. This study is therefore dedicated to examining the educational competencies of education majors in STEM to fundamentally contribute to teachers' professional development. With the guidance of teachers, if learners can develop literacy in interdisciplinary thinking at a young age and effectively use STEM thinking to analyse and solve problems, they will be more capable of coping with global challenges in their learning work and adapting to the rapidly developing world of the future.

2. Literature Review

In today's world, countries are actively developing STEM education. According to Li & Wang, from 2014 to 2018, there has been a significant increase in publications and readers of international journals about STEM education, and the quality of publications is improving [1]. This proves that even though STEM education is in its early stages as a new field, it still attracts sufficient attention globally. Sahin et al. also suggest that STEM education is attracting much attention, and she believes that STEM is entering phase 2.0 as an essential trend in education [2].

In STEM disciplines, educators can assess student achievement more objectively. STEM education can disregard functionally irrelevant factors, such as gender, religion, sex and ethnicity, better than traditional education [3]. This implies that STEM education is more generalised compared to non-STEM education. STEM education is often used in educational policies or curriculum choices in schools. The relevant knowledge covers cognitive analytical approaches, integrated cognitive approaches, data production and analysis and statistically related knowledge.

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3. Research Methodology

3.1 Research instrument

According to the STEM Teacher Competency Rating Standards (Trial) released by China in 2018, the STEM teacher rating standards are divided into five dimensions, which are STEM education value understanding, STEM discipline foundation, STEM interdisciplinary understanding and practice, STEM curriculum development and integration, and STEM teaching implementation and evaluation [4]. This study selects three of these dimensions, namely STEM educational value understanding, STEM interdisciplinary understanding and practice, and STEM teaching implementation and evaluation, which are evaluation indicators of STEM teachers' intrinsic personal qualities, such as professional knowledge and interdisciplinary understanding, and the current status of teachers' indicators related to curriculum development, teaching implementation, and feedback evaluation, respectively. This study utilised a quantitative survey to explore STEM education competencies among education majors. The questionnaire draws on Yang's STEM teaching competency questionnaire for teacher educators [5]. Three dimensions were selected: STEM education value understanding dimension, interdisciplinary integration competency, and STEM teaching implementation competency. After conducting a reliability analysis by pretest to ensure the quality of the questionnaire, the current level of STEM education competency of teacher-training students was investigated by distributing and returning the questionnaire. Then, the quantitative processing and analysis were conducted based on the data returned from the questionnaire to provide real and reliable data for further research.

3.2 Research subjects

There are two parts to the questionnaire: in the first part, it examined what information education majors had about their experiences with STEM education; in the second part, it examined the current state of teacher educators' STEM education competency, and the questions were developed in accordance with the revised STEM education competency framework for teacher educators. The questions were all based on a five-point Likert scale. The two parts of the survey consisted of 19 questions. A total of 221 valid questionnaires were collected and analysed using SPSS 22.0 software.

3.3 Reliability and validity analysis of the questionnaire

Table 1. Cronbach's reliability analysis

Number of items	Sample size	Cronbach alpha coefficient
19	221	0.888

As shown in Table 1, the reliability coefficient value is 0.888, which is higher than 0.8, indicating that the study data are highly reliable. The reliability coefficient for the "alpha coefficient of item deleted" does not increase significantly after any question item is removed, which indicates that the question item should not be removed. Overall, the study data reliability coefficient value is greater than 0.8, indicating that the data are reliable and suitable for further analysis.

Table 2. KMO and Bartlett's test

KMO value		0.829t
Bartlett's test for sphericity	Approximate chi-square	892.753
	df	171
	p-value	0.000

When the KMO test value exceeds 0.7, factor analysis is appropriate. Also, the larger the approximate chi-square value of Bartlett's spherical test, the greater the significance value is less than 0.001, and vice versa. Using KMO and Bartlett's test, Table 2 data were confirmed as valid: the KMO value was 0.829, which indicates a good level of validity as the study data are suitable for extracting information.

4. Findings of the study

4.1 Effect of gender and age on the level of competence in STEM education

Table 3. Results of t-test analysis

Analysis item	Item	Sample size	Mean	Standard deviation	Mean difference	Difference 95% CI	t	df	p
A1	Male	19	2.68	0.95	-0.45	-0.977 ~ 0.074	-1.707	98.000	0.091
	Female	81	3.14	1.06					
	Total	100	3.05	1.05					
A2	Male	19	3.68	0.89	-0.14	-0.544 ~ 0.258	-0.707	98.000	0.481
	Female	81	3.83	0.77					
	Total	100	3.80	0.79					

Analysis item	Item	Sample size	Mean	Standard deviation	Mean difference	Difference 95% CI	t	df	p
A3	Male	19	3.16	0.83	-0.66	-1.006 ~ -0.308	-3.731	98.000	0.000**
	Female	81	3.81	0.65					
	Total	100	3.69	0.73					
A4	Male	19	3.74	0.93	-0.13	-0.602 ~ 0.347	-0.554	23.809	0.585
	Female	81	3.86	0.75					
	Total	100	3.84	0.79					
A5	Male	19	3.21	1.08	-0.49	-0.927 ~ -0.059	-2.256	98.000	0.026*
	Female	81	3.70	0.80					
	Total	100	3.61	0.87					
B1	Male	19	3.53	0.90	0.03	-0.416 ~ 0.481	0.144	98.000	0.886
	Female	81	3.49	0.88					
	Total	100	3.50	0.88					
B2	Male	19	3.63	0.83	-0.04	-0.452 ~ 0.381	-0.167	98.000	0.868
	Female	81	3.67	0.82					
	Total	100	3.66	0.82					
B3	Male	19	3.37	0.90	-0.10	-0.505 ~ 0.304	-0.494	98.000	0.622
	Female	81	3.47	0.78					
	Total	100	3.45	0.80					
B4	Male	19	3.47	1.07	-0.11	-0.646 ~ 0.432	-0.410	22.365	0.686
	Female	81	3.58	0.76					
	Total	100	3.56	0.82					
B5	Male	19	2.84	1.17	-0.47	-0.945 ~ 0.012	-1.934	98.000	0.056
	Female	81	3.31	0.89					
	Total	100	3.22	0.96					
C1	Male	19	3.74	1.05	-0.34	-0.863 ~ 0.188	-1.330	22.381	0.197
	Female	81	4.07	0.74					
	Total	100	4.01	0.81					
C2	Male	19	3.47	0.90	0.03	-0.413 ~ 0.471	0.131	98.000	0.896
	Female	81	3.44	0.87					
	Total	100	3.45	0.87					
C3	Male	19	3.58	1.07	0.01	-0.406 ~ 0.428	0.053	98.000	0.958
	Female	81	3.57	0.76					
	Total	100	3.57	0.82					
C4	Male	19	3.58	0.96	-0.19	-0.573 ~ 0.200	-0.958	98.000	0.341
	Female	81	3.77	0.71					
	Total	100	3.73	0.76					
C5	Male	19	3.53	0.96	-0.08	-0.524 ~ 0.367	-0.350	98.000	0.727
	Female	81	3.60	0.86					
	Total	100	3.59	0.88					

Analysis item	Item	Sample size	Mean	Standard deviation	Mean difference	Difference 95% CI	t	df	p
C6	Male	19	3.53	0.90	-0.08	-0.488 ~ 0.330	-0.381	98.000	0.704
	Female	81	3.60	0.79					
	Total	100	3.59	0.81					
* p<0.05 ** p<0.01									

Table 4. ANOVA results

	The grade level is (mean ± standard deviation)					F	p
	Freshman year (n=3)	Sophomore year (n=1)	Junior year (n=4)	Senior year (n=29)	Graduate student (n=63)		
A1	3.00±2.00	2.00±null	3.25±0.50	3.21±1.11	2.98±1.01	0.503	0.733
A2	4.00±1.00	4.00±null	3.50±0.58	3.66±0.90	3.87±0.75	0.574	0.682
A3	3.67±1.15	3.00±null	3.50±0.58	3.83±0.66	3.65±0.77	0.578	0.679
A4	4.00±1.00	3.00±null	3.25±0.50	3.93±0.80	3.84±0.79	0.972	0.427
A5	3.67±1.15	5.00±null	3.50±1.00	3.93±0.84	3.44±0.84	2.305	0.064
B1	4.33±0.58	4.00±null	3.00±0.00	3.52±0.83	3.48±0.93	1.090	0.366
B2	3.33±1.53	5.00±null	3.50±0.58	3.72±0.80	3.63±0.81	0.881	0.478
B3	3.67±1.15	4.00±null	3.25±0.50	3.52±0.83	3.41±0.80	0.315	0.867
B4	3.67±1.15	5.00±null	3.75±0.50	3.69±0.81	3.46±0.82	1.263	0.290
B5	3.67±1.15	4.00±null	3.50±0.58	3.52±0.91	3.03±0.97	1.768	0.142
C1	4.00±1.00	3.00±null	4.25±0.96	4.07±0.75	3.98±0.83	0.521	0.721
C2	3.33±1.53	4.00±null	4.00±0.82	3.62±0.82	3.33±0.86	1.082	0.370
C3	3.67±1.15	4.00±null	3.25±1.26	3.66±0.81	3.54±0.80	0.322	0.862
C4	4.00±1.00	3.00±null	4.00±0.82	3.76±0.74	3.70±0.78	0.474	0.755
C5	3.67±1.15	5.00±null	3.50±1.00	3.66±0.77	3.54±0.91	0.746	0.563
C6	3.67±1.15	4.00±null	3.75±0.96	3.62±0.73	3.56±0.84	0.145	0.965
* p<0.05 ** p<0.01							

The independent sample t-test was used to analyse the differences in STEM educational competencies of education students by gender, and the data results are shown in Table 3. p-values for most of the dimensions were greater than 0.05, indicating that there were no significant differences between genders in the dimensions of STEM educational competencies of teacher educators.

One-way ANOVA was used to analyse the variance of STEM education ability of teacher educators in different grades (Table 4), and most of the p-values of each dimension were greater than 0.05, indicating that the differences in STEM education ability of teacher educators in different grades were not significant, and none of them showed significant differences.

4.2 Descriptive statistical analysis of each dimension

4.2.1. Analysis of the current dimensions of STEM education ability

Table 5. Descriptive statistics of education majors' STEM education competency status

Name	n	Minimum	Maximum	Mean	Standard deviation	Median
A1	221	1.000	5.000	3.050	1.048	3.000
A2	221	1.000	5.000	3.800	0.791	4.000
A3	221	2.000	5.000	3.690	0.734	4.000
A4	221	1.000	5.000	3.840	0.788	4.000
A5	221	1.000	5.000	3.610	0.875	4.000

According to Table 5, the mean value of option A1 "I understand the meaning and characteristics of STEM education", tends to be average. However, the standard deviation is large, indicating that education majors significantly differ in this issue. A small number of education students still need to learn more about STEM education, and the popularity rate needs to be enhanced. Except for A1, all other values are above 3.5, indicating that most education majors have a preliminary understanding of STEM education, including option A2, "I think STEM education will promote the development of students' comprehensive quality and ability", and option A4 "I am very interested in STEM education and think it is very meaningful to develop STEM education. The mean value of options A2, "I think STEM education will promote students' comprehensive quality and ability development", and A4, " I am interested in STEM education and think it is very meaningful to develop STEM education", exceeds 3.8. Meanwhile, the standard deviation of A2 to A5 is small, indicating that most education majors recognise the importance and replicability of STEM education. The overall data show that education majors lack confidence in their STEM education ability or are generally conservative in their self-evaluation.

4.2.2. Analysis of STEM interdisciplinary integration competency dimensions

Table 6. Descriptive statistics of STEM interdisciplinary integration competencies of education majors

Name	n	Minimum	Maximum	Mean	Standard deviation	Median
B1	221	1.000	5.000	3.500	0.882	4.000
B2	221	1.000	5.000	3.660	0.819	4.000
B3	221	2.000	5.000	3.450	0.796	3.000
B4	221	1.000	5.000	3.560	0.820	4.000
B5	221	1.000	5.000	3.220	0.960	3.000

According to Table 6, in this dimension, the mean value of each item does not vary much. It is basically around 3.5, which indicates that the interdisciplinary integration ability of education majors is moderate to high. The mean value of option B2 "I am able to transfer knowledge by linking it to my discipline when learning a new curriculum", is 3.66, indicating that most of the surveyed students can actively integrate across disciplines. Option B5: "I have learned and mastered certain interdisciplinary integration theories (curriculum integration) and methods, such as project-based, inquiry-based learning, 6E teaching method, etc." has a mean value of 3.22, which indicates that education majors lack learning of interdisciplinary integration methods and do not know enough about specific methods. In general, most teacher education students are aware of interdisciplinary integration, but the ability of STEM curriculum development and integration is average.

4.2.3. Analysis of STEM teaching implementation and evaluation dimensions

Table 7. Descriptive statistics of STEM teaching implementation and evaluation for education students

Name	n	Minimum	Maximum	Mean	Standard deviation	Median
C1	221	1.000	5.000	4.010	0.810	4.000
C2	221	1.000	5.000	3.450	0.869	3.000
C3	221	1.000	5.000	3.570	0.820	4.000
C4	221	1.000	5.000	3.730	0.763	4.000

Name	n	Minimum	Maximum	Mean	Standard deviation	Median
C5	221	1.000	5.000	3.590	0.877	4.000
C6	221	1.000	5.000	3.590	0.805	4.000

According to Table 7, in this dimension, the mean value of each item ranges from 3.45 to 4.01, which is moderately high. In comparison, the mean value of option C1, "I think constructing a context is more conducive to knowledge learning", exceeds 4, which indicates that most education majors agree that constructing a context is important for learning. According to option C4, most of the education majors can express their ideas clearly, so the overall ability of teacher education students to practice STEM teaching is good.

5. Discussion

It can be found through this study that the STEM education concept is widely recognised. However, the overall status of education majors' STEM education competency is at an intermediate level, and the self-evaluation of education majors' STEM education competency is generally conservative. The results of this study show that gender and grade level are not decisive factors in STEM education competency. The tradition has been that education majors gain a deeper understanding of STEM education as their grade levels rise, but this study shows that there is no significant difference between upper-grade students and lower-grade students in terms of their understanding of STEM education. STEM teaching training has yet to be fully available, and education majors still need to receive systematic education.

One of the core spirits of STEM education is the integration of disciplines. Scholars have conducted a series of studies on the organic integration between disciplines to promote students' problem-solving, independent construction of knowledge, and inquiry learning in the face of authentic situations. Research shows that most education majors recognise the interdisciplinary nature of STEM education [6]. However, there are still multiple factors to consider when implementing STEM education. Firstly, schools vary widely in terms of STEM education resources. Knowledgeable and experienced teachers significantly impact student motivation in STEM education. Secondly, family factors are also important in influencing STEM education outcomes, such as home environment, family climate, and family parenting styles. The strategies and resources of middle-class parents may inspire children to see careers in science as a natural and attainable possibility. Furthermore, STEM education also emphasises individual competencies, and spatial thinking is one of the primary factors that determine success [7].

Training can be carried out in four areas in response to the current problems.

1. STEM education value understanding: Cultivate education majors' awareness of STEM education; universities can offer special STEM teaching courses for education majors, pay attention to differences, gender and career development, and promote balanced development of STEM education [8].
2. STEM teaching capacity cultivation: teacher cultivation and on-the-job training, enriching the curriculum form of STEM education, forming a STEM education ecosystem, and promoting the sharing of STEM regional education resources. Improve teachers' STEM specialisation [9].
3. Interdisciplinary integration ability cultivation: pay attention to the curriculum design of disciplinary integration, increase the integration of disciplines, and organically combine humanities and social sciences with natural sciences [10].
4. STEM curriculum development cultivation: using technology to assist STEM education, future research could focus on designing and developing STEM education tools or learning platforms to support students in knowledge construction and scientific innovation [11].

In addition, the current study still has some limitations, as the current scale also presents a 1:3 result for the ratio of men to women due to the current situation of more women than men in the teaching profession in general. Additionally, STEM education resources are unevenly distributed around the world, and both funding and availability determine the degree to which education majors are aware of STEM education [7]. Therefore, the development of STEM education must be connected to teacher training and resource allocation.

6. Conclusion

Although the current outlook for STEM education is very promising and most education majors recognise it and understand its purpose in cultivating the spirit of innovation and practical skills, the need for teacher training and resource allocation is still huge. By investigating the current status of education majors' competency level for STEM, this study presents the current problems. It gives future development directions, expecting that in the future, relevant departments can actively develop STEM courses. Universities can offer special STEM teaching courses for education majors, pay attention to differences and promote the balanced development of STEM education. This study still has the limitations of the sample, and the future research direction should also study how to provide a perfect curriculum and teacher training model for the development of STEM education and increase the integration of disciplines while paying attention to the development of STEM education. It should also increase the integration of disciplines, train better teachers to help cultivate students' innovative thinking and scientific literacy in problem-solving, and promote the innovation, participation, and universality of STEM education.

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