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The Impact of STEM Teaching Model on Physics Student Teachers' Awareness and Readiness

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Abstract

This study used a pre-experimental research design with a quantitative survey. The study utilized the STEM teaching model developed in the previous study and implemented five STEM teaching practices for physics student teachers (PSTs) over two months. Descriptive and inferential statistical methods were used to analyse the data. The study showed that before the intervention study, PSTs had a low awareness of STEM education (mean = 2.525; standard deviation (SD) = 0.681) and a low level of readiness (mean = 2.786; SD = 0.718). After the experiment, both means increased significantly, reaching 3.83 (SD = 0.70) and 3.51 (SD = 0.91), respectively. Inferential statistics showed that there were significant changes in the STEM awareness and readiness of PSTs before and after the experiment (both $p < .01$;). The results of the Paired T-test showed Cohen's d of 0.912 and 0.558, respectively, which have a large and moderate effect. In summary, the STEM teaching model had a positive impact on the awareness and readiness of PSTs and provided an effective way to cultivate and improve the STEM capabilities of PSTs.

Keywords STEM Education, student Teacher, STEM Teaching Model, STEM awareness, STEM readiness

INTRODUCTION

STEM (Science, Technology, Engineering and Mathematics) is currently a hotspot and an important direction in global education reform, each country has planned its own STEM development framework and path. Educators believe that the competitiveness of the next generation of children can be improved by developing their problem-solving skills and creativity through STEM education [1-5]. The use of STEM education can stimulate students' interest in learning and improve their academic performance, which will help them acquire 21st century knowledge and skills， as well as generate solutions for problems [6-7]. In the context of the information age and today's rapid development of science and technology, STEM education has become one of the most important concepts for cultivating digital technology talent.

Around 2007, STEM education entered the field of vision of Chinese education researchers [8]. After more than ten years of development, STEM education has achieved phased results in China, improving the innovation and practical abilities of the people. Research has found that teachers' awareness of STEM education is relatively low, with an average score of 3.44 out of 5 [9]. The main difficulty encountered by schools in promoting STEM education is a shortage of teachers. However, one factor in the success of STEM education is teachers [10]. They are the driving force of change and are responsible for implementing the new curriculum and taking STEM education to another level in the field of education [11-12]. Teachers play a very important role in implementing educational transformation. Without their active participation, it is difficult to achieve the goals set by educational management [13]. The level of STEM awareness and the level of preparation of teachers play a crucial role in the level of STEM education [14]. Many foreign scholars have conducted a large number of studies on STEM teachers in this regard and believe that improving the STEM awareness and readiness of student teachers is an important way to solve the shortage and improve the ability of STEM teachers. In China, student teachers are reserve teachers and the successors of future STEM teachers. However, student teachers in China have their own characteristics and special needs for STEM education. They not only need to master STEM skills to meet the challenges of the 21st century but also need to master STEM teaching skills to be qualified to work as STEM teachers in primary and secondary schools. It is crucial for them to break away from the influence of the deeply rooted traditional subject-based education.

This study takes physics student teachers (PSTs) in China as the research object, implements STEM teaching activities through the STEM teaching model developed through previous research, and explores the impact of the STEM teaching model on the STEM awareness and readiness of PSTs. The aim is to obtain ways to improve and cultivate the STEM teaching ability of PSTs, to fill this research gap, and to provide theoretical and policy references for improving the level of STEM teachers in primary and secondary schools in China and cultivating qualified STEM teachers.

Accordingly, the research questions of this study are as follows:

(1) What is the STEM awareness level of PSTs?
(2) What is the STEM readiness level of PSTs?
(3) Does the STEM teaching model have a significant impact on STEM awareness and readiness of PSTs in STEM practice?

METHODS

Research design

Based on the characteristics of student teachers in physics, their requirements for STEM education and their future STEM teaching needs, the researchers designed a STEM teaching model suitable for them [15]. The teaching procedure of the model consists of eight steps: pre-analysis, create a context, problem analysis, define tasks, develop a proposal, implement project, communication and evaluation, reflection and improvement. The researchers designed five cases of STEM teaching practice activities to be implemented according to the STEM teaching model that created. A questionnaire survey was conducted before and after the experiment, and the quantitative analysis was used to examine the pre- and post-survey STEM awareness and readiness of the student teachers, and the impact of the STEM teaching model on the STEM awareness and readiness.

As the educational design involves students in complete classes, randomly assigning students may interrupt the original classroom environment in an educational institution [16-17]. Due to government enrollment policy restrictions, only one class of about 50 students is allowed to enroll in the physics major each year. The situation of students in different majors and grades is different, there is a risk that it will affect the results unnecessarily, therefore, this study utilised a pre-experimental survey design, applying both pre-survey and post-survey.

Sample

Participants were recruited from students majoring in physics education at Hanjiang Normal University in Hubei, China, with a total of 198 PST, distributed as shown in Table 1.

Table 1 Number of Samples

Year	Male	Female	Number
First-year-2022	23	29	52
Second-year-2021	24	19	43
Third-year-2020	34	19	53
Fourth-year-2019	34	16	50
Total	115	83	198

Note, the first number in "X-year-Y" represents the year and the second number represents the year of enrolment, e.g. "Third year-2020" represents the third year of PSTs, who were enrolled in 2020.

The pre-survey and post-survey participant samples were divided into two cases:

(1) All four years, 198 students, participated in the pre-survey to obtain information about the general level of STEM awareness and readiness of the student teachers before the experiment.

(2) The researchers conducted a survey study of the STEM teaching model with the 53 students in the third year. The researchers could not perform this study on all 198 samples and therefore used cluster random sampling. Replacing the four classes with small balls with codes 1-4, and then grabbed one of them at random, the class Third year-2020 was randomly selected. The researchers extracted pre-survey data for Third year-2020 from all four grades of total data by grade level markers to compare with post-survey data and examine the impact of the STEM teaching model on STEM awareness and readiness.

Instrument

This instrument used is a questionnaire and this questionnaire consists of two scales: the STEM Awareness Scale and the STEM Readiness Scale. The STEM awareness and STEM readiness scales are based on five-point Likert scales. Both scales are available in English and Chinese, with the Chinese version for PSTs. Before the formal survey, 35 students from the third year-2020 science education program participated in a pilot study, and their characteristics were similar to those of the formal sample in this study, and the reliability and validity are shown in the Table 2. The questionnaires were proofread by experts for content and structure to ensure quality and validity. The first part of the survey collected students' personal information and demographic background, including gender, class, and student ID. Questionnaires were administered to the sample group in the presence of the researcher to monitor the process and clarify any confusing questions.

Table 2 Reliability and Validity of the Questionnaire

Items	Reliability Cronbach's Alpha	Validity		
		KMO	Bartlett's Test of Sphericity	
			Approximate Chi-square	p
Awareness	0.935	0.761	385.977	< .001
Readiness	0.908	0.778	193.321	< .001

The implement of STEM teaching practice activities

In this study, five STEM teaching practice activities were conducted with physics student teachers using the developed STEM teaching model, as shown in the Table 3. For each teaching activity, a complete STEM teaching practice activity guide was developed by the researchers, consistent with the STEM teaching model. The researchers ensured that all research processes were carried out in accordance with this guideline. Each program was divided into eight steps and each activity lasted approximately four hours.

Table 3 Five STEM Teaching Practice Activities

No	STEM teaching practice activities	Title of textbook (People's Education Publishing House, 2012)
1	Holographic Imaging - The Art of Light and Shadow Naked Eye 3D	Grade 8, Chapter 4, Light Phenomena, Section 3, Imaging with a plane mirror, P77
2	Homemade Simple Binoculars	Grade 8, Chapter 5, Lenses and Their Applications, Section 5, Microscopes and Telescopes, P103
3	Homemade periscope	Grade 8, Chapter 4, Light Phenomena, Section 3, Imaging with plane mirrors: Hands-on Physics, P80
4	Homemade Camera	Grade 8, Chapter 5, Lenses and Their Applications, Section 2, Lenses in Life: Think and Do, P94.
5	Making a Solar Oven	Grade 8, Chapter 4, Light Phenomena, Section 3, Imaging with a Plane Mirror: World of Science, P79

Data analysis

The researcher statistically analysed the data obtained from the questionnaire by SPSS 29 (Statistical Package for the Social Sciences). The survey data was entered into the statistical analysis software to calculate the mean and standard deviation (SD). In addition, normality tests were conducted to select parametric or non-parametric tests. If the p-value is greater than 0.05, the data may follow a normal distribution and the data collected will be subjected to a parametric test, i.e. t-test. If the data is not normally distributed, a non-parametric test is used.

RESULTS AND DISCUSSION

The level of STEM awareness and readiness of physics student teachers before the STEM teaching practice activities

Descriptive statistics of the test results of the STEM awareness and readiness scale for all samples in the four years are shown in the table 4. The mean values of STEM awareness and readiness were 3.05 and 2.93, and the standard deviations (SD) were 0.58 and 0.77. The overall of the findings suggests that there is some dispersion in STEM awareness and readiness, but not much. The overall level of STEM awareness and readiness of student teachers before the STEM teaching practice activities was poor, and the clear majority of them did not have the ability to use STEM teaching models to teach.

Table 4 STEM Awareness and Readiness of Pre-Survey

Items	Mean	SD
Awareness	3.05	0.58
Readiness	2.93	0.77

The level of STEM awareness and readiness of physics student teachers after the STEM teaching practice activities

The descriptive statistics of the STEM awareness and readiness scale test results for the 53 samples in Third year-2020 after the quasi-experiment are shown in the Table 5. The mean values of STEM awareness and readiness were 3.83 and 3.51, and the standard deviation (SD) was 0.70 and 0.91. The overall of the findings suggests that there is some dispersion in STEM awareness and readiness, and that the individual differences are slightly larger than before the STEM teaching practice activities. After the activity, the student teachers' level of awareness and readiness of STEM education increased substantially relative to the pre-survey.

Table 5 STEM Awareness and Readiness of Post-survey

Items	Mean	SD
Awareness	3.83	0.70
Readiness	3.51	0.91

The impact of STEM teaching model on PSTs' awareness and readiness

Firstly, a normal distribution test was conducted to examine the difference between the students' changes in STEM awareness and Readiness before and after the STEM teaching practice activities. The results are shown in Table 6. Because of the sample size of the research is greater than 50, thus using the Kolmogorov-Smirnov test, sig.>0.05, does not present significance, which means that the original hypothesis is accepted (the original hypothesis: the data are normally distributed), so it is normality. Therefore, we use paired t-test below to compare the differences in STEM awareness and readiness of student teachers before and after the STEM teaching practice activities.

The results of the paired t-test are shown in Table 6, which shows a significant variability at the 0.01 level between the pre-survey and post-survey of STEM awareness ($t=-6.51$, $p=0.000<0.01$). Specific comparison of the variability shows that the mean value of pre-test (3.05), is significantly lower than the mean value of pre-survey (3.83). $t=6.51$ indicates the magnitude of the mean difference in relation to the variability, with larger t-values showing a greater difference. Cohen's d is the measure of effect size in paired samples t-test. It is used to measure the size of the difference in means between two paired samples. Typically, larger values of Cohen's d indicate more significant mean differences and larger effects (Rosenthal et al., 1994). The value of Cohen's d for STEM awareness before and after the STEM teaching practice activities is 0.912, which can be considered a relatively large effect.

Table 6 Tests of Normality

Items	Kolmogorov-Smirnov[a]		Shapiro-Wilk	
	Statistic	p	Statistic	p
Diff-Awareness	0.111	0.160	0.945	0.020
Diff-Readiness	0.070	0.767	0.982	0.610

Note: Diff-Awareness is the difference between pre-survey and post-survey of STEM awareness; Diff-Readiness is the difference between pre-test and post-test of STEM Readiness.

Therefore, there is a significant change in student teachers' STEM awareness before and after the implementation of the STEM teaching model, and this change was statistically significant ($p < 0.01$) with a large effect size (Cohen's $d = 0.912$), which means that the implementation of our STEM teaching model had a large positive contributing effect on student teachers' awareness.

The situation of STEM readiness we also can see in Table 7. The level of pre-survey and post-survey of STEM readiness also showed significant variability at the 0.01 level ($t=-3.985$, $p<0.01$) with a t-value of -3.985. A comparison of the differences shows that the mean value of pre-survey (2.93) is significantly lower than the mean value of post-survey (3.51). Paired samples t-test effect size Cohen's d value of 0.558, which indicates a medium-sized effect size. This means that the implementation of STEM teaching model had a large positive facilitating impact on student teachers' readiness. This can be learnt and implemented in the design and evaluation of our STEM education policy interventions.

Table 7 The Results of the Paired T-test

Items	**Third year-2020 (M±SD)**		***t***	***p***	**Cohen's d**
	Pret-survey	Post-survey			
Pre-Awareness *Paired* Post-Awareness	3.05±0.58	3.83±0.70	6.51	<0.01	0.912
Pre-Readiness *Paired* Post-Readiness	2.93±0.77	3.51±0.91	3.985	<0.01	0.558

Note: Pre-Awareness is pre-survey STEM awareness, post-Awareness is post-survey STEM awareness; Pre-Readiness is pre-survey STEM readiness, post-Readiness is post-survey STEM readiness; Pre-survey is Third year-2020 level data drawn from the four years pre-survey, and post-survey is Third year-2020 data after STEM teaching practice activities.

CONCLUSION

By analysing the data from the questionnaire, we found that the overall level of STEM awareness and readiness was low before the STEM teaching practice activities. Although STEM education has been carried out in China for more than ten years, due to the lack of STEM education resources, the influence of the traditional education system, and the shortage of STEM teachers, the overall level of development of STEM education in China is not very high, and the opportunities for student teachers to contact with STEM education are very few, and their STEM awareness and readiness are lower overall.

Through the STEM teaching model, student teachers' STEM awareness and readiness changed significantly after the STEM teaching practice activities, producing a large positive improvement. This indicates that our STEM teaching model can improve student teachers' STEM awareness and readiness. Teachers' STEM awareness has an important role in guiding teachers to conduct STEM teaching. Good STEM awareness and readiness can guide teachers to integrate STEM into classroom teaching practice and implement it successfully to achieve the set teaching goals when teachers are conducting the lesson preparation stage [18].

STEM education plays an important role in developing 21st century skills [19-20]. The core elements of these skills are identified as problem solving, collaboration, critical thinking, creativity, self-awareness, and digital literacy [21-22]. STEM education is well positioned to develop these 21st century skills. In this context, teachers in the 21st century are expected to have a high level of STEM education skills in order to foster students' creativity, apply scientific research methods and techniques, and have an entrepreneurial and innovative mindset. For STEM teachers, it is important to correctly adopt STEM teaching models and teaching concepts, thus, they can become a qualified teacher and cultivate qualified talents with comprehensive development to meet the needs of the 21st century in various aspects. Therefore, it is essential to cultivate STEM awareness and readiness in student teachers during their university studies stage.

The results of this study show that STEM Awareness and readiness can be improved through STEM teaching practice, which in turn improves their STEM teaching skills. Educational policymakers and pre-service teacher trainers can use this information to develop STEM teacher training programs and cultivate qualified STEM teachers.

DECLARATION OF INTEREST

There is no conflict of interest with this study.

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