

**EXPLORING THE IMPACT OF STEM TEACHING
MODEL ON HANJIANG NORMAL UNIVERSITY
PHYSICS STUDENT TEACHERS' AWARENESS
AND READINESS IN PERFORMING
STEM PRACTICES**

**SULTAN IDRIS EDUCATION UNIVERSITY
2025**



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Kampus Sultan Abdul Jalil Shah



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ABSTRACT

This study developed a STEM teaching model based on the characteristics and needs of physics student teachers (PSTs), and explored the impact on STEM awareness and readiness of PSTs. This study used explanatory sequential mixed methods. Quantitative data were obtained through questionnaires, while qualitative data were obtained using semi-structured interviews and open-ended questions. All research instruments were evaluated by experts, and the Individual Content Validity Index (I-CVI) was equal to 1.00. The study employed a pre-experimental research design. All 198 PSTs were selected to answer the questionnaire to get initially STEM awareness and readiness. Then, 53 PSTs were chosen to use the cluster sampling method as a research sample. Based on design-based research, Five STEM teaching practice activities were implemented over two months in first cycle and another activity was implemented based on the improved STEM teaching model in the second cycle. The survey data was analysed using descriptive and inferential statistics. The study revealed that the PSTs had poor awareness (mean = 2.525; SD = 0.681) and low-level readiness (mean = 2.786; SD = 0.718) before the intervention study. Following the pre-experimental, both mean values experienced a considerable increase, reaching 3.83 (SD = 0.70) and 3.51 (SD = 0.91), respectively. No significant differences existed between males and females in STEM awareness and readiness ($p = .853$ and $.135$) of pre-survey, compared substantial differences in post-survey ($p < .001$ and $p = .033$). In addition, Spearman's analysis showed a moderate-strength positive correlation between STEM awareness and readiness ($r = 0.504$, $p < .01$). Semi-structured interviews and open-ended questions triangulated the questionnaire results. In conclusion, the STEM teaching model developed in this study has positive impact on the STEM awareness and readiness of PSTs and provides an effective way to develop and enhance the STEM capabilities of PSTs.





**MENEROKA IMPAK MODEL PENGAJARAN STEM TERHADAP
KESEDARAN DAN KESEDIAAN GURU PELAJAR FIZIK
HANJIANG NORMAL UNIVERSITY DALAM
MELAKSANAKAN AMALAN STEM**

ABSTRAK

Kajian ini membangunkan model pengajaran STEM berdasarkan ciri dan keperluan guru pelajar fizik (PST), dan meneroka kesan terhadap kesedaran dan kesediaan STEM terhadap PST. Kajian ini menggunakan kaedah campuran berurutan penerangan. Data kuantitatif diperoleh melalui soal selidik, dan data kualitatif diperoleh menggunakan temu bual separa berstruktur dan soalan terbuka. Semua instrumen kajian telah dinilai oleh pakar, dan Indeks Kesahan Kandungan Individu (I-CVI) adalah bersamaan dengan 1.00. Kajian ini menggunakan reka bentuk penyelidikan pra-eksperimen. Kesemua 198 PST telah dipilih untuk menjawab soal selidik untuk mendapatkan kesedaran dan kesediaan STEM pada mulanya. Kemudian, 53 PST telah dipilih untuk menggunakan kaedah persampelan kelompok sebagai sampel kajian. Berdasarkan penyelidikan berasaskan reka bentuk, Lima aktiviti amalan pengajaran STEM telah dilaksanakan selama dua bulan dalam kitaran pertama dan satu lagi aktiviti dilaksanakan berdasarkan model pengajaran STEM yang telah ditambah baik dalam kitaran kedua. Data tinjauan dianalisis menggunakan statistik deskriptif dan inferensi. Kajian itu mendedahkan bahawa PST mempunyai kesedaran yang lemah (min = 2.525; SD = 0.681) dan kesediaan tahap rendah (min = 2.786; SD = 0.718) sebelum kajian intervensi. Berikutan pra-eksperimen, kedua-dua nilai min mengalami peningkatan yang ketara, masing-masing mencapai 3.83 (SD = 0.70) dan 3.51 (SD = 0.91). Tiada perbezaan ketara wujud antara lelaki dan perempuan dalam kesedaran dan kesediaan STEM ($p = .853$ dan $.135$) pra-kaji selidik, berbanding perbezaan yang ketara dalam tinjauan pasca ($p < .001$ dan $p = .033$). Di samping itu, analisis Spearman menunjukkan korelasi positif kekuatan sederhana antara kesedaran dan kesediaan STEM ($r = 0.504$, $p < .01$). Temu bual separa berstruktur dan soalan terbuka membuat triangulasi keputusan soal selidik. Kesimpulannya, model pengajaran STEM yang dibangunkan dalam kajian ini memberi kesan positif terhadap kesedaran dan kesediaan STEM PST dan menyediakan cara yang berkesan untuk membangun dan meningkatkan keupayaan STEM PST.



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LIST OF ABBREVIATIONS

3D	Three Dimensions
AHP	Analytic Hierarchy Process
AIR	American Institutes for Research
AR	Augmented Reality
CITC	Corrected Item-Total Correlation
CVI	Content Validity Index
DBR	Design-Based Research
df	degree of freedom
DOE	Department of Education
FDM	Fuzzy Delphi Method
I-CVI	Individual Content Validity Index
KMO	Kaiser-Meyer-Olkin
IYPT	International Young Physicists' Tournament
MOE	The Ministry of Education
NRC	National Research Council
NSB	National Science Board
PBL	Problem-Based Learning
PjBL	Project-Based Learning
PSTs	Physics Student Teachers





RO	Research Objective
RQ	Research Question
SAS	STEM Awareness Scale
S-CVI	Scale Content Validity Index
SD	Standard Deviation
SNA	Social Network Analysis
SPSS	Statistic Package for Social Science
SRS	STEM Readiness Scale
STEAM	Science, Technology, Engineering, Art, and Mathematics
STEM	Science, technology, engineering, and mathematics
TBL	Team-Based Learning
UPSI	<i>Universiti Pendidikan Sultan Idris</i>
VR	Virtual Reality
WOS	Web of Science



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CHAPTER 1

INTRODUCTION

1.1 Introduction



STEM (science, technology, engineering, and mathematics) education influences global K-12 reforms. Its integration is essential for cultivating future generations' innovative problem-solving skills and developing the critical competency required in the 21st century (Chai et al., 2020a, 2020b; Li et al., 2020).

The programmatic recommendations for integrating science, mathematics, engineering, and technology education, which is frequently seen as the start of STEM education, were first stated explicitly in the 1986 report Undergraduate Science, Mathematics, and Engineering Education by the United States National Science Board (NSB, 1986; Sanders, 2009). STEM education entered the vision of Chinese educational researchers around 2007 (Qin, 2007). STEM education in China has made specific achievements after more than a decade of development and has improved the





national innovation capability and practical skills. However, many problems exist, such as the lack of STEM professional teachers, localised teaching models, insufficient resources for STEM teaching, and the imbalance of regional development.

In China, student teachers represent the primary source of future educators, and their STEM competency and ability to teach within the STEM model directly influence the development of the next generation of STEM professionals and the nation's future. However, the STEM education model, primarily adapted from foreign educational systems, lacks sufficient localisation. This misalignment results in inefficiencies, producing limited outcomes despite increased effort (Zhuang et al., 2020). Since student teachers possess distinct characteristics and specific needs in STEM education, developing a STEM teaching model tailored to their unique context is crucial. This approach will enhance their STEM competency and teaching skills in China.

The problem of insufficient STEM teachers is a bottleneck that restricts the development of STEM education in China, accounting for 65.18%; thus, solving the problem of STEM teachers is imminent (STEM Education Research Centre of the Chinese Academy of Educational Sciences, 2019). STEM awareness and readiness are essential factors in STEM capabilities, providing a foundation for individuals to develop STEM competency (Mustafa et al., 2017). For teachers, STEM awareness and readiness determine teachers' inclination toward using the STEM teaching model (Sulaiman et al., 2017). STEM awareness and readiness impact the results of their implementation of the STEM teaching model (Buyruk & Korkmaz, 2016a). Therefore, it is necessary to develop STEM awareness and readiness at the student teachers'





learning stage to improve their ability to organise teaching using the STEM teaching model.

STEM teaching models emphasise interdisciplinarity, practicality, innovation, and student-centred thinking (Bryan et al., 2016; Hmelo-Silver, 2004; Kolodner et al., 2003). Based on the instructional goals and forms of implementation, the main existing STEM instructional models are 5E teaching model (Bybee, 2009; Ong et al., 2020), 6E teaching model (Hsiao et al., 2024; Yang, 2023), project based learning model (PjBL) (DeFillippi, 2001; Diana & Sukma, 2021), problem-based learning (PBL) model, Smith et al., 2022; Kwan & Tam, 2009), team-based learning (TBL) model (Arcas, 2024; Parappilly et al., 2019), PIRPOSAL teaching model (Artika et al., 2024; Yata et al., 2020). Current research hotspots and innovations in teaching models focus on technology-enhanced models (e.g., virtual simulation experiments (Moore et al., 2020), AI-assisted personalised teaching (Luckin et al., 2016)); and socio-culturally contextualised models (e.g., SSI (Socioscientific Issues) integration (Zeidler, 2016), localised cases (Zhang et al., 2021)); and younger model innovations (gamified learning (Bers et al., 2019), story-driven STEM (Pantoya et al., 2015)). Current challenges in implementing STEM teaching models are most centred on the superficial integration of disciplinary subjects, with some classrooms simply overlaying content from the four disciplines and lacking deep connections (English, 2017). Difficulty transitioning teacher roles, with many STEM teachers still maintaining their status as knowledge transmitters and failing to transition well into interdisciplinary coordinators (Nadelson et al., 2013).





1.2 Research Background

Under the trend of global educational reform, STEM education is increasingly valued by the education sector in various countries. The STEM teaching model emphasises the transmission of subject knowledge and cultivates students' comprehensive qualities such as problem-solving skills, critical thinking, innovation, and teamwork (Ahonen & Kinnunen, 2015; Van Laar et al., 2020). The uniqueness of the subject of physics and its important position in STEM education make it an ideal direction for research on STEM education.

i. The central position of the subject of physics in STEM education

The subject of physics is an integral part of STEM (science, technology, engineering, and mathematics) education, providing students with a foundation for understanding natural phenomena, scientific principles, and technological applications. Physics is not only a way to describe and explain the world, but it also helps students develop problem-solving skills through mathematical modelling, experimentation, and the application of technology. Physics is a core subject in STEM education. Studying physics can help students explore in depth how scientific principles, experimental methods, and technological applications can promote the overall goals of STEM education and promote students' critical thinking, problem-solving skills, and interdisciplinary learning.

ii. The experimental and practical nature of physics

Physics emphasises experimentation and practice and helps students understand and verify physical laws and theories through observation, experimentation, measurement,





and data analysis. STEM education emphasises practical and hands-on abilities, and physics' experimental nature is highly compatible with the STEM education concept. Physics' experimental methods and practical abilities are important components of STEM education. Studying the experimental design and implementation process in physics can help discover how practical work and scientific exploration can enhance students' interest and understanding.

iii. Challenges and opportunities for interdisciplinary integration

One of the core objectives of STEM education is to promote interdisciplinary integration between disciplines. Physics is closely linked to other disciplines, such as mathematics, chemistry, and engineering. Many concepts and applications of physics (such as mechanics, thermodynamics, electromagnetism, and quantum mechanics) require knowledge from other disciplines to understand and solve. As an important discipline in STEM education, physics provides students with practical opportunities for interdisciplinary integration through integration with other disciplines (such as mathematics and engineering). Studying the interdisciplinary application of physics in STEM education can provide valuable experience and theoretical support for designing and implementing interdisciplinary courses.

iv. Develop students' critical thinking and problem-solving skills

Physics uses reasoning and quantitative analysis to understand natural phenomena, allowing students to exercise critical thinking and solve complex problems. STEM education emphasises developing students' ability to innovate and solve real-world problems, and physics cultivates these abilities through problem-solving in practice. Physics develops students' analytical skills, critical thinking, and the ability to solve





practical problems, which is highly consistent with the goals of STEM education. Studying how the physics discipline can achieve these goals in STEM education can help further strengthen the development of critical thinking and innovation in STEM education.

v. Technological applications and innovation in the physics discipline

Physics has many applications in technological fields, especially in modern science, technology, and engineering development. For example, physics applications in quantum computing, laser technology, new energy sources, and materials science have all contributed to technological innovation and scientific progress. STEM education places particular emphasis on developing innovative capabilities in technology and engineering, and the technological applications of physics undoubtedly provide a wealth of material for this purpose. Physics is the cornerstone of technological and engineering development. Studying physics in STEM education can help students understand how to apply physics principles to practical technology and engineering, stimulate their innovative thinking, and scientific exploration.

vi. The importance of the subject of physics in training future engineers and scientists

Physics provides a solid foundation for future engineers and scientists. Many core principles of engineering and technology disciplines originate from physics, such as mechanics, electricity, thermodynamics, fluid mechanics, etc. In STEM education, physics is the 'language of science' and the 'foundation of engineering', cultivating students' ability to understand and apply scientific principles. Physics is the foundation of many technical disciplines. Studying the role of physics in STEM education helps to





understand how to cultivate future engineers, scientists, and technical experts, while enhancing their scientific literacy and technical skills.

vii. The contribution of physics to creativity and technological literacy

Physics is concerned with theory, experimentation, technological innovation, and application. STEM education encourages students to develop creative thinking, and physics helps students develop independent creativity by exploring natural phenomena and proposing innovative solutions to problems. Physics provides students with a source of creative thinking. Through an in-depth study of the subject, it is possible to reveal how to inspire creativity and improve technological literacy in students through teaching practice, supporting the cultivation of an innovative talent for the future.



viii. Innovative teaching models in physics



The teaching model of the physics discipline itself is constantly being innovated. From traditional lecture-based teaching to introducing various teaching methods such as experimental teaching, inquiry-based learning, project-based learning, and flipped classrooms, STEM teaching in the physics discipline has a wide range of practical and research space. The teaching methods of the physics discipline are highly compatible with the concept of STEM education. Researching the innovation of teaching models in the physics discipline can help explore and improve teaching strategies in STEM education, and enhance students' interest in learning and subject literacy.

In short, physics occupies an important position in STEM education. Studying STEM education in physics promotes innovation in physics education and helps students develop critical thinking, innovation, and interdisciplinary integration skills.





By studying the role of physics in STEM education, we can provide students with a more comprehensive educational experience, promote their in-depth understanding and application of science, technology, engineering, and mathematics, and cultivate innovative talents for the future.

STEM education, which transcends the pervasive divide between natural sciences and social sciences, is potentially unique in its ability to promote the awareness and participation of new generations and address the social, economic, and environmental aspects of global challenges (Lay & NG, 2021). This interdisciplinary and practice-oriented teaching method is suitable for physics, as it depends highly on experiments and applications and requires a high level of scientific literacy from both students and teachers. With the widespread promotion of STEM education in primary and secondary schools, cultivating physics student teachers (PSTs) with STEM teaching ability has become an essential issue for teacher training colleges (Cherrstrom et al., 2017; Ryu et al., 2019; Shernoff et al., 2017).

However, despite the advantages of STEM teaching models, existing studies have found that, in practice, student teachers often face challenges in understanding and applying STEM education concepts and teaching methods (Hsu & Fang, 2019; Kelley & Knowles, 2016; Thibaut et al., 2018). STEM awareness and readiness of PSTs as potential implementers of STEM teaching directly affect the effectiveness of future STEM teaching. Therefore, studying the impact of the STEM teaching model on STEM awareness and readiness of PSTs not only reveals the problems encountered in the teacher training process, but also provides a valuable basis for optimising STEM teaching.





In current educational research, some scholars have explored the impact of STEM education. However, most studies focus on implementing STEM teaching in primary and secondary schools, lacking research on how STEM teaching models in teacher education affect student teachers, particularly in physics. STEM awareness and readiness of PSTs under the STEM teaching model have not received sufficient attention (Cinar et al., 2016; Ecevit et al., 2024; Siew et al., 2015). This research gap not only hinders the comprehensive development of STEM education but also results in a mismatch between the training of physics teachers and the needs of STEM education. Therefore, this study aims to fill this gap by exploring how the STEM teaching model impacts STEM awareness and readiness of PSTs, providing theoretical support and practical guidance for STEM teacher education in teacher training universities.



PSTs have their own characteristics and needs for STEM education. Most of the widely used STEM teaching models come from abroad, and many are unsuitable for PSTs in China. This study is guided by research-based design (DBR). By investigating the characteristics of PSTs and their needs for STEM education, a ‘Stem-Pst’ STEM teaching model suitable for PSTs was developed, with ‘S’ capitalised in ‘Stem’ to emphasise ‘Science’ (Physics) and ‘Pst’ is based on the first letter of the English word ‘Physics student teachers’, representing the STEM teaching ideas and STEM teaching methods. STEM teaching practice activities were designed, and two iteration cycles were conducted to change and improve the STEM teaching model. With the constructivist learning theory as the theoretical framework, it is believed that teachers’ STEM awareness and readiness are gradually constructed through interaction, feedback, and practice. From this perspective, PSTs’ awareness and readiness for STEM teaching





can be seen as a dynamic development process. Through this theoretical perspective, this study will explore in-depth teachers' understanding, acceptance, and practical application of the STEM teaching model, as well as the STEM awareness and readiness that impact these abilities, in order to propose helpful teacher education strategies and provide new theoretical support and practical reference for future STEM teacher education.

1.3 Problem Statement

Though it has advanced recently, STEM education in China still has a long way to go and faces many obstacles. These challenges are reflected in the education system's structure and teaching methods, but also involve allocating educational resources, training teachers, and enhancing students' innovation ability. In particular, there is an urgent need to improve STEM education even more and direct its growth toward more creativity and applicability, given how quickly science and technology are developing worldwide. By thoroughly analysing the following main difficulties currently influencing STEM education in China, this research seeks to solve these urgent concerns. The research findings guide the development of policies and future changes to enhance STEM education.

- i. There is no suitable STEM teaching model for PSTs. Chinese PSTs have their characteristics and needs for STEM education, and most of the popular STEM teaching models originate from overseas, which are not very suitable for Chinese PSTs (Dong et al., 2020). Therefore, this study developed a



suitable STEM teaching model for PSTs according to their characteristics and needs for STEM education.

ii. PSTs' STEM competency and STEM teaching skills direly need improvement.

STEM education is essential for developing 21st century skills, and it is crucial for PSTs in the 21st century to possess both a high level of STEM competency and practical STEM teaching skills. On the one hand, they must show strong STEM capabilities to meet the challenges of the 21st century. On the other hand, they need to apply these STEM teaching skills to cultivate students' STEM abilities. Thus, addressing both dimensions is critical for the adequate readiness of future educators. Educators must focus on these two aspects when cultivating 21st century PSTs.

iii. The overall STEM awareness and readiness level among PSTs is not very

high. STEM awareness and readiness are two essential aspects of teachers' STEM competence. Teachers' STEM awareness and readiness influence the selection of teaching strategies during the teaching design process. The lack of a suitable STEM teaching model is one of the most important reasons for the failure of STEM teaching, and improving teachers' STEM awareness and readiness is necessary to develop an effective STEM teaching model (Seymour et al., 2019). The pre-survey found that PSTs' STEM awareness and readiness are relatively low (Refer to Chapter 5.2.3). Most PSTs cannot use the STEM teaching model, and improving their STEM awareness and readiness can solve the problem.

iv. Exploring the differences in STEM awareness and readiness between male

and female PSTs. Gender differences have been a topical issue in STEM education. Studies have found that there are significant differences between

males and females in STEM education, with females performing poorly in STEM education activities because of self-selection bias and stereotype threat theory (Buck et al., 2020; McNally, 2020; Tandrayen-Ragoobur, 2021; Weeden et al., 2020). STEM awareness and readiness significantly impact learning STEM education and implementing the STEM teaching model; whether a significant difference between male and female PSTs in STEM awareness and readiness will be revealed.

- v. Seeking ways to increase STEM awareness and readiness among PSTs. PSTs' STEM awareness and readiness are essential for implementing STEM education. According to the Research Report on STEM Education in China, insufficient STEM teachers have become the main reason affecting the development of STEM education in China, accounting for 65.18%; thus, solving the problem of STEM teachers is imminent (STEM Education Research Centre of the Chinese Academy of Educational Sciences, 2019). By exploring the impact of the STEM teaching model on PSTs' STEM awareness and readiness, the researcher seeks to improve PSTs' STEM competence, which is of great significance for improving the level of STEM education in China.

1.4 Research Objectives

This study explores the impact of implementing the STEM teaching model on the STEM awareness and readiness of PSTs. The sample of the study is the student teachers



of the physics program (undergraduate) at Hanjiang Normal University, where the author works. The research objectives of the study are:

1. To design a STEM teaching model based on experts' and PSTs' agreement.
2. To explore the PSTs' awareness level toward STEM education.
3. To explore the PSTs' readiness level toward STEM education.
4. To determine the impact of a STEM teaching model on the PSTs' awareness and readiness.

1.5 Research Questions

1. What STEM teaching model is appropriate for PSTs?

1.1 What are the experts' and PSTs' needs for the STEM teaching model?

1.2 Is the developed STEM teaching model for PSTs applying STEM practices in physics learning valid?

2. What is the PSTs' awareness level of STEM education?

2.1 Is there any significant gender difference in PSTs' awareness of STEM education between male and female students?

2.2 Is there any significant difference in PSTs' awareness of STEM education from first-year to fourth-year?

3. What is the PSTs' readiness for STEM education?

3.1 Is there any significant gender difference in PSTs' readiness toward STEM education between male and female students?

3.2 Is there any significant difference in PSTs' readiness toward STEM education from first-year to fourth-year?



4. Is there any significant impact of the STEM teaching model on the PSTs' awareness and readiness in performing STEM practices?
 - 4.1 Is there any significant difference in STEM awareness in performing the STEM teaching model in learning physics between pre-survey and post-survey of students who participated in the STEM practices?
 - 4.2 Is there any significant gender difference in STEM awareness in performing the STEM teaching model in learning physics between male and female students who participated in the STEM practices?
 - 4.3 Is there any significant difference in STEM readiness in performing the STEM teaching model in learning physics between pre-survey and post-survey of students who participated in the STEM practices?
 - 4.4 Is there any significant gender difference in STEM readiness in performing the STEM teaching model in learning physics between male and female students who participated in the STEM practices?
 - 4.5 Is there any significant relationship between PSTs' awareness and readiness towards implementing STEM practices?
 - 4.6 How can instructors' and PSTs' opinions be used to improve the STEM teaching model?

1.6 Research Hypothesis

The research hypotheses were identified and tested.

H_{01} : There is no significant gender difference in PSTs' awareness of STEM education between male and female students.

H₀₂: There is no significant difference in PSTs' awareness toward STEM education from first-year to fourth-year.

H₀₃: There is no significant gender difference in PSTs' readiness toward STEM education between male and female students.

H₀₄: There is no significant difference in PSTs' readiness toward STEM education from first-year to fourth-year.

H₀₅: There is no significant difference in STEM awareness in performing the STEM teaching model in learning physics between pre-survey and post-survey of students who participated in the STEM practices.

H₀₆: There is no significant gender difference in PSTs' awareness of the STEM teaching model in learning physics between males and females who participated in the STEM practices.

H₀₇: There is no significant difference in males' STEM awareness in performing the STEM teaching model in learning physics between pre-survey and post-survey who participated in the STEM practices.

H₀₈: There is no significant difference in females' STEM awareness in performing the STEM teaching model in learning physics between those who participated in the STEM practices pre-survey and post-survey.

H₀₉: There is no significant difference in STEM readiness in performing the STEM teaching model in learning physics between pre-survey and post-survey of students who participated in the STEM practices.

H₁₀: There is no significant gender difference in PSTs' readiness toward the STEM teaching model in learning physics between males and females who participated in the STEM practices.

H₁₁: There is no significant difference in males' STEM readiness in performing the STEM teaching model in learning physics between pre-survey and post-survey who participated in the STEM practices.

H₁₂: There is no significant difference in females' STEM readiness in performing the STEM teaching model in learning physics between pre-survey and post-survey who participated in the STEM practices.

H₁₃: There is no significant relationship between PSTs' awareness and readiness in the pre-survey towards implementing STEM practices.

H₁₄: There is no significant relationship between PSTs' awareness and readiness in the post-survey towards implementing STEM practices.

1.7.1 Limitations

1. This study is limited to student teachers majoring in physics in the selected sample area, and the results may not be fully generalised to student teachers in other areas or from different backgrounds.
2. This study relies on questionnaires and interviews, which may be subject to response bias. Samples may not express their views and feelings fully, honestly, or accurately.
3. Because of time constraints, the number of teaching cases implemented in this study and the limited time available may have limited the identification of causal relationships.

4. Limited to the government admission policy, physics majors have only one class per grade, and there is a difference between PSTs of different grades. Accordingly, there is no fully equivalent control group to choose from. This study uses a pre-experimental research design and a one-group pre-test and post-test design.

1.7.2 Delimitations

1. The pre-experiment conducted in this study was delimited to one of the four classes of physics majors in our university, randomly selected for a two-month short-term training.

2. This study focused solely on exploring the impact of the STEM teaching model on PSTs' awareness and readiness.

3. This study used quantitative research (questionnaires) and qualitative research (semi-structured interviews and open-ended questions) to fulfil its research questions and objectives.

4. The same scale was used for the pre-test and post-test, although this can cause the test-retest effect (Xiao et al., 2019), which was not considered in this study.

5. This study focuses on the impact of the STEM teaching model on PSTs' STEM awareness and readiness. To be consistent with the school's regular teaching arrangement and teaching sequence, the selected STEM projects are from the junior high school physics textbook in China, and more attention is paid to their grasp of the STEM teaching model.



1.8 Significance of the Study

Currently, China is facing the problem of insufficient STEM teachers and their low quality, and the traditional teaching model of single subjects and fragmented knowledge has not usefully addressed this challenge. Traditional teacher education has apparent deficiencies in cultivating STEM awareness and readiness in future teachers, resulting in a low overall level of STEM knowledge among teacher candidates, which makes it difficult for them to adapt to the complex STEM teaching needs of the future.

First, STEM education, as a critical area of global educational reform, requires teachers to have interdisciplinary integration skills, innovative teaching methods, and the ability to solve practical problems. However, current student teachers in China are not adequately prepared in these areas, which affects the quality of STEM teacher training. Therefore, developing a STEM teaching model suitable for Chinese student teachers is necessary to improve their comprehensive literacy and teaching ability in the STEM field.

Second, traditional subject teaching places too much emphasis on single-subject knowledge and ignores the intersection and integration between subjects, which cannot meet the needs of STEM education for comprehensive, practical, and innovative talents. This study aims to lay the foundation for the training of future STEM teachers by constructing and implementing a STEM teaching model that meets the actual situation of Chinese student teachers and by enhancing their STEM awareness and readiness through interdisciplinary teaching methods and practical learning tasks.





Finally, STEM awareness and readiness are essential factors in STEM knowledge. This study explores the impact of the STEM teaching model on STEM awareness and readiness, hoping to provide empirical evidence for improving the STEM knowledge of Chinese student teachers and provide a reference for formulating and implementing relevant education policies through research findings. In current education reform, exploring how to cultivate high-quality STEM teachers through a teaching model is significant in promoting the comprehensive development of STEM education in China.

In addition, STEM practice is an essential form of organisation and means of achieving STEM education. Because STEM education emphasises hands-on practical skills and the ability to solve real-world problems, many scholars regard STEM practice as an essential connotation of STEM education (Li et al., 2020b). STEM practice usually refers to students learning science, technology, engineering, and mathematics in real-world contexts through hands-on experiments, projects, and practical applications. It is an essential development of STEM education, and it stimulates students' interest and deepens their understanding of STEM subjects through specific practice activities and experiments. In this study, the impact of the STEM teaching model on PSTs' STEM awareness and readiness was explored by implementing five STEM teaching practice activities. Physics student teachers (PSTs) face unique challenges in STEM education, mainly because of their professional background and learning characteristics.





i. A learning style that emphasises theory.

Physics is a highly theoretical subject emphasising mathematical derivation, formula application, and quantitative analysis. In traditional physics education, many courses focus on abstract theories and computational methods, lacking opportunities for practical application, technological innovation, and interdisciplinary integration. This makes PSTs likely to engage in purely theoretical teaching or research work, lacking an in-depth understanding of practical application, technological implementation, and engineering design in STEM education.

(a) Lack of interdisciplinary skills: PSTs are mainly exposed to physics principles and mathematical tools in traditional physics teaching, while STEM education requires students to can integrate knowledge across disciplines, such as applying physics principles to engineering technology, programming, or mathematical modelling.

(b) Weak application skills: PSTs may lack the confidence and experience to translate physics knowledge into practical operations, technology development, or engineering design. As physics education focuses on theoretical understanding and lacks practical hands-on practice, adapting to the practical operation and innovation skills emphasised in STEM education is difficult.

ii. The single-subject nature of physics and the interdisciplinary requirements of STEM education.

Physics, as a discipline within STEM, is highly specialised. However, STEM education promotes interdisciplinary collaboration and emphasises the integrated application of science, technology, engineering, and mathematics. This requires students to not only





master physics but also understand the basic principles and practical skills of other disciplines, such as programming technology, engineering design, and mathematical modelling.

(a) Interdisciplinary knowledge blind spots: PSTs focus on in-depth learning of the physics discipline during their studies, while they have relatively little knowledge of other STEM fields (such as computer science, engineering, technological innovation, etc.). Even for interdisciplinary content, there is often a lack of systematic learning and practice, which is an inevitable difficulty in STEM education.

(b) Difficulty adapting to technological tools: In STEM education, technological tools such as computer programming, data analysis, and simulation experiments are widely used. PSTs may not be familiar with these technical tools, and their mastery of programming languages and mathematical modelling in particular may become a barrier to their STEM education.

iii. Emphasis on knowledge transmission, neglecting innovation and practice.

Physics education usually focuses on knowledge transmission, emphasising the understanding and memorising physical laws and formulas. However, STEM education emphasises students' innovative thinking, hands-on ability and teamwork when solving practical problems. STEM education advocates a project-driven, problem-based learning approach to cultivate students' innovative awareness and engineering practice ability.

(a) Innovation awareness is insufficiently cultivated: The education model for PSTs focuses more on accumulating theoretical knowledge and standardised



problem-solving skills, which may neglect students' ability to innovate and operate in practical problems. STEM education requires students to develop innovative thinking through project practice and experimental exploration, which differs from traditional physics education.

- (b) Lack of practical teaching experience: PSTs usually have a more systematic classroom theoretical study, but may lack practical teaching or project experience. In STEM education, project-based learning, teamwork, hands-on experimentation and the application of technology are very important components, which require PSTs to actively participate in practical teaching design, project development, and engineering practice.

iv. Transformation of traditional teaching methods and educational concepts.

The traditional teaching methods of PSTs are relatively monotonous, usually focusing on transmitting knowledge points and explaining theorems, lacking interactivity and flexibility. On the other hand, STEM education emphasises interaction, collaboration, interdisciplinary thinking, and the ability to solve practical problems, and advocates student-led learning rather than simply teacher lectures. This shift in educational philosophy may be a challenge for PSTs.

- (a) Difficulties in changing teaching methods: PSTs are used to traditional teaching methods. STEM education emphasises project-driven and self-directed learning, which requires teachers to design interactive teaching activities that stimulate students' desire to explore and their ability to get their hands dirty. This requires PSTs to make major adjustments to their teaching concepts and methods.

- (b) Assessment and feedback methods are not adapted: STEM education often focuses on students' project results, innovative thinking, teamwork and problem-solving abilities, rather than purely theoretical examinations. This assessment method may be uncomfortable for PSTs who are used to traditional assessment methods, and they need to rethink how to design assessments and feedback.

v. Lack of adequate educational technology support.

PSTs may not have been exposed to various educational technology tools widely used in STEM education, such as virtual experiment platforms, programming environments, and online collaboration tools. In the continuous development of digital education, STEM education often relies on these tools to promote student learning and innovation.

- (a) Educational technology application shortcomings: PSTs mostly use traditional teaching methods in physics teaching, while STEM education emphasises using modern educational technology tools, such as virtual simulations and programming teaching platforms. This may require additional learning and adaptation for PSTs.

- (b) Insufficient educational resources: Some PSTs may lack sufficient STEM educational resources in their schools or educational environments, including equipment, platforms, and technical support, which may limit their implementation of STEM education.

In short, the difficulties PSTs face in learning STEM education mainly comes from their professional background, traditional teaching methods, limitations of the discipline, and insufficient mastery of interdisciplinary knowledge and technology.



Solving these problems requires adjustments and improvements PSTs' educational philosophy, teaching methods, and technological tools. Schools and the education system need to provide them with broader interdisciplinary training and practical opportunities to adapt to STEM education's increasingly complex and diverse requirements. Based on this, this study selected PSTs as the research sample, and sought ways to improve their STEM capabilities by developing STEM teaching models and implementing STEM teaching practices. They seek ways to improve their STEM abilities and their ability to learn physics.

Therefore, this study focuses on analysing the impact of an innovative STEM teaching model on STEM awareness and readiness among PSTs. It intends to provide a practical solution to the shortage of STEM teachers in China and contribute to the overall improvement of STEM education in the country.

Physics as an important part of STEM education, plays an irreplaceable role in cultivating students' scientific literacy, critical thinking, problem-solving ability and innovation ability. STEM education aims to cultivate students' ability to solve complex problems through the interdisciplinary integration of the four disciplines of science, technology, engineering, and mathematics. Physics, as one of the 'basic sciences' in STEM, has a unique role and significance.

i. Physics is a fundamental discipline in STEM education.

Physics is the natural science that studies matter, energy, and their interactions. As one of the fundamental sciences, physics provides a solid theoretical foundation for STEM education. Many engineering technologies and applied sciences (such as electrical





engineering, materials science, aerospace, information technology, etc.) are based on physics principles. Through the study of physics, students can understand the basic laws of nature and provide scientific theoretical support for the learning and innovation of other disciplines. Bunyamin et al. (2020) indicated that physics is the foundation of all scientific and engineering disciplines. It provides a scientific method and tools for understanding the natural world, and these tools and methods are also widely used in technology and engineering design. Physics plays a vital role in STEM education.

ii. The subject of physics is an important vehicle for cultivating critical thinking and problem-solving skills.

Physics teaching is not just about learning the laws and formulas of physics, but more importantly, about problem-solving through scientific experiments and reasoning.

Physics emphasises the combination of theory and experiment. It requires students to make hypotheses, design experiments, collect data and analyse them when faced with complex physical problems, cultivating their critical thinking and scientific inquiry skills. Widayanti et al. (2019) indicated that STEM education focuses on transmitting subject knowledge and developing critical thinking, innovation, and collaboration skills in solving practical problems. Physics helps students develop these abilities through complex experiments and problem-solving tasks. Physics can effectively cultivate students' logical reasoning and problem-solving abilities by challenging their thinking.

iii. Physics can better integrate with technology, engineering, and mathematics. Physics is closely related to other STEM disciplines, such as technology, engineering, and mathematics. Mathematical modelling and technological applications in physics are essential for technological and engineering innovation, while many technical





problems in engineering also require the help of physics principles. STEM education advocates interdisciplinary integration, and physics provides a bridge for interdisciplinary collaboration, enabling students to understand and apply multidisciplinary knowledge to solve practical problems. Soros et al. (2018) emphasise that physics requires many mathematical and technological capabilities, especially in physical modelling and experimental design. STEM education promotes students' understanding of complex systems by integrating physics with other disciplines. This interdisciplinary learning model improves students' subject knowledge and helps them apply this knowledge to practical technology and engineering.

iv. Physics can arouse students' interest in science and inspire their innovative spirit.

Physics not only helps students understand scientific principles but also arouses their interest in exploration. STEM education advocates stimulating students' innovative spirit through project-based learning and practical activities. Physics experiments and engineering projects, especially those involving advanced technology and future challenges (such as quantum computing, energy, environmental protection, etc.), can stimulate students' creativity and cultivate their innovative abilities in science and engineering. Yuliati et al. (2018) believe that innovative experiments and technological projects in physics can stimulate students' interest in science and cultivate their innovative thinking. Through the teaching of physics, students can not only master knowledge but also explore new technologies through practical experience, promoting social and technological progress.





v. Physics provides scientific support for solving global challenges.

Modern society faces many complex global challenges, such as climate change, the energy crisis, and ethical issues brought about by technological progress. Physics provides the theoretical basis and technical support for solving these problems. For example, physics is widely used to develop new energy sources, climate modelling, breakthroughs in information technology and other fields. Markus et al. (2021) pointed out the key role of physics in solving climate change, energy, and environmental problems, providing scientific support for STEM education to solve global challenges. Through studying physics, students can acquire an in-depth understanding of these complex issues and contribute to future scientific and technological solutions.

vi. Modernising physics education promotes the overall development of STEM

education.

As science and technology progress, the direction of physics research is also evolving. The rise of emerging fields such as quantum physics, nanotechnology, and artificial intelligence has placed new demands on STEM education. Modernising physics education not only provides students with innovative knowledge of advanced science and technology, but also promotes the overall development of STEM education, enabling students to adapt to the rapidly changing technological environment. According to Martyniuk et al. (2021), the innovative and interdisciplinary development of modern physics requires STEM education to keep up with the forefront of science and technology. Reforms and innovations in physics education will not only help students master the latest science and technology but also enhance their competitiveness in the future field of science and technology.





In short, the study of physics, as an important part of STEM education, is of irreplaceable significance. Physics provides a solid theoretical foundation and interdisciplinary application framework for STEM education. It promotes students' scientific literacy and technical ability by cultivating their critical thinking, problem-solving skills and innovative spirit. The physics teaching not only stimulates students' interest in science but also provides scientific support for global challenges and promotes the development of society and technology. Therefore, studying physics is essential for improving and developing STEM education, laying the foundation for students to succeed in science, technology and engineering.

This study explores the impact of implementing the STEM teaching model on the STEM awareness and readiness of PSTs through implementing STEM teaching practice activities. It provides a reference for improving the PSTs' STEM knowledge and teaching ability using the STEM model in their future careers. The significance of the study is as follows:

- i. Developed a STEM teaching model tailored to PSTs.

PSTs have various characteristics that differ from other groups; although there are many widely used STEM teaching models, they are not suitable for China PSTs (Ong et al., 2020; So et al., 2021; Yeung et al., 2022; Zhan et al., 2021). This study developed a STEM teaching model tailored to PSTs based on the characteristics of PSTs and the needs of STEM education. This STEM teaching model can be further applied to the future training of PSTs to enhance their STEM knowledge and teaching skills. It lays a strong foundation for their professional careers and helps address the shortage of STEM





educators in primary and secondary schools. Ultimately, this contributes little value to advancing STEM education in China.

ii. This study adopts a mixed methods research approach, which combines qualitative and quantitative methods to compensate for the limitations of a single method and to enhance the depth and credibility of the research through data triangulation.

(a) Complementary advantages. Quantitative research provides macro trends and statistical significance (e.g., ‘the correlation between STEM awareness and grade level’), but cannot explain the ‘why’ or ‘how’. Qualitative research reveals the underlying mechanisms (e.g., ‘the motivation behind juniors’ sudden increase in STEM interest’), but lacks universality. Mixed models can use an explanatory sequential design, the combination of “breadth + depth” is achieved (Creswell & Plano Clark, 2018). (b) Triangulation. Cross-verification of qualitative data (semi-structured interviews, open-ended questionnaires) and quantitative data (scales): (1) Testing consistency (e.g., the quantitative survey found that ‘third-year students are highly prepared for STEM’, which is related to the fact that some students interviewed had participated in STEM activities); (2) Explaining contradictions (e.g., the quantitative survey found that ‘third-year students have a higher awareness of STEM than fourth-year students,’ and the reasons were found in the interviews).

iii. Improving the STEM competence of PSTs.

Competition in the 21st century has become increasingly intense, and research has shown that STEM education offers a more practical approach to developing the skills necessary to meet these challenges (Li et al., 2016). The aim of implementing STEM





education is mainly to improve students' competence (Heil, 2013): (a) Develop 21st century new skills; (b) To increase students' attitudes and interest in STEM fields; (c) To enhance students' achievement, knowledge, and understanding of STEM courses; (d) To promote students' understanding of technology, engineering, and scientific processes.

iv. Enriching the teaching skills of PSTs.

When a graduating student teacher applied for a teaching position at a school in Hangzhou, China, the examiner asked, "What is the general teaching process in the STEM teaching model?" The student could not respond, and the application outcome failed. PSTs are typically not exposed to STEM-based teaching approaches and undergo much training in traditional teaching paradigms. PSTs need specialised training since they are more likely to work in STEM education, with teaching concepts and methods different from traditional education. Through the mastery of STEM teaching models, the development of teaching abilities, and integrating STEM concepts into their teaching practice, PSTs could improve the quality and efficacy of education in particular.

v. Exploring the impact of the STEM teaching model on PSTs' STEM awareness and readiness.

As the main force of future teaching in primary education, PSTs' awareness and readiness for STEM play an essential role in performing their duties. It will not only affect teaching effectiveness but also their future position development. STEM awareness and readiness significantly impact the successful implementation of the STEM teaching model, and PSTs about to enter the STEM teaching field should focus on developing their STEM awareness and readiness. By exploring the impact of the



STEM teaching model on PSTs' STEM awareness and readiness, this study provides an idea and a reference for training STEM teachers, which can contribute to solving the shortage of STEM teachers and improving the level of STEM education in China.

This study explored the impact of implementing the STEM teaching model on PSTs' STEM awareness and readiness. Research gaps filled by this study are as follows:

i. Obtained Eight elements need to be satisfied with the STEM teaching model suitable for PSTs using FDM.

Based on the characteristics of PSTs and their need for STEM education, through consulting experts by FDM , eight elements need to be fulfilled in the STEM teaching model: a) improve students' ability to solve physics problems; b) promote the development of students' engineering creativity; c) develop students' thinking skills; d) improve students' collaborative skills in learning physics; e) maintain students' motivation to learn physics; f) develop students' self-confidence; g) improve critical thinking skills; and h) keep students focused on learning physics.

ii. AHP was used to select the best STEM teaching model prototype to meet the needs of PSTs.

Using the eight elements as the criteria layer and the six commonly used STEM teaching models as the alternatives layer, the AHP selected the best STEM teaching model prototype that meets the needs. The alternatives were evaluated and ranked using the AHP: PjBL scored 0.343, PBL scored 0.289, TBL scored 0.085, 6E scored 0.095, PIRPOSAL scored 0.094, and 5E scored 0.061. Based on the overall ranking of the alternative levels, the best alternative was PjBL with a quantitative score of 0.343. This indicates that PjBL is the most suitable alternative for elementary students among the



alternatives. Suggests that PjBL is the STEM teaching model prototype that best meets the characteristics and needs of elementary school students among the alternatives.

iii. In current educational research, some scholars have explored the impact of STEM education. However, most studies focus on implementing STEM teaching in primary and secondary schools, lacking research on how STEM teaching models in teacher education affect student teachers, particularly in physics. STEM awareness and readiness of PSTs under the STEM teaching model have not received sufficient attention (Cinar et al., 2016; Ecevit et al., 2024; Siew et al., 2015). This research gap not only hinders the comprehensive development of STEM education but also results in a mismatch between the training of physics teachers and the needs of STEM education. Therefore, this study filled this gap by exploring how the STEM teaching model impacts STEM awareness and readiness of PSTs, providing theoretical support and practical guidance for STEM teacher education in teacher training universities.

iv. Developed a STEM teaching model based on PjBL suitable for PSTs. Most of the widely used STEM teaching models come from abroad, and many are unsuitable for Chinese PSTs. This study was guided by investigating the characteristics of PSTs and their needs for STEM education; a PjBL-based STEM teaching model was developed through design-based research (DBR).

v. STEM teaching activities were implemented using the developed STEM teaching model. It was found that implementing STEM teaching activities for PSTs can significantly improve their STEM awareness and preparedness, which has not been





reported in previous literature. This provides ideas for cultivating qualified STEM teachers.

1.9 Operational Definitions

The operational definition used in the study was defined as follows:

i. STEM awareness

Awareness refers to the state or ability to perceive, feel, or be conscious of something. It involves having knowledge or understanding of a particular situation, issue, or thing. STEM awareness refers to teachers' awareness of STEM education. STEM awareness is more than a superficial understanding of STEM disciplines; it is a profound grasp of how these disciplines are interrelated and apply to real-world problem-solving (Bybee, 2010). From a philosophical point of view, STEM awareness refers to the ability to recognise and control one's understanding of STEM education and its application through STEM practice activity. This study refers to the PSTs' awareness, perceptions, and understanding of STEM education, as well as the increase of the tendency and probability to adopt the STEM teaching model in their teaching process by improving STEM awareness. This study measures it through a STEM awareness survey adopted by Buyruk and Korkmaz (2016b).



ii. STEM readiness

STEM readiness in this study refers to the STEM teaching readiness of PSTs. According to Abdullah et al. (2017), there are three levels of STEM teaching readiness: (a) Cognitive, which refers to a teacher's ability to think creatively and critically; (b) Affective, which describes their emotional readiness to do their job. (c) Behavioural readiness, on the other hand, is teachers' actual knowledge and abilities in doing something new. Teachers who are motivated and have a high level of readiness will be more confident and accept the tasks given to them (Boset & Asmawi, 2020). STEM readiness in this study refers to the basic skills PSTs should have to successfully implement STEM teaching to become qualified STEM teachers, measured by the STEM readiness survey in this study—the STEM readiness scale developed by the Friday Institute for

iii. Impact

Impact means to affect something and describe the significance or result of an event, decision, or discovery on an individual, group, or society. This study implemented five STEM teaching practice activities according to the developed STEM teaching model, and another STEM teaching practice activity was implemented based on the improved STEM teaching model in the second cycle. Then, the changes in STEM awareness and readiness of the PSTs before and after the experiment were studied through questionnaires, semi-structured interviews and open-ended questions to determine whether implementing the STEM teaching model impacted the PSTs' STEM awareness and readiness.



1.10 Summary

The STEM teaching model integrates science, technology, engineering, and mathematics. Its main characteristics are interdisciplinarity, innovation, practicality, and teamwork. In China, the development of STEM education has been relatively slow, and most theories, practical cases, and teaching models have been copied from abroad and are not very suitable for the Chinese educational environment. While physics discipline is an important part of STEM education, the lack of STEM teachers in China is a significant bottleneck in its development. PSTs are the primary source of future STEM teachers, and cultivating their STEM abilities and skills in using STEM teaching models to implement teaching is related to future STEM education development in China. STEM awareness and readiness are important factors of STEM ability.



Therefore, this study takes the actual situation of Chinese education into account, uses physics teachers as a sample, and combines the needs and characteristics of physics teachers to develop a STEM teaching model suitable for them. The impact of STEM awareness and readiness on them is explored by implementing STEM teaching practices.

