Exploring Teachers' Perceived Competence in STEM Education in a National Pilot Middle School of STEM Education in Mainland China

Chunyang Liao* and Alex Wing Cheung Tse

Faculty of Education, The University of Hong Kong, Hong Kong SAR, China
Email: u3596869@connect.hku.hk (C.L.); awctse@hku.hk (A.W.C.T.)
*Corresponding author

***Abstract*—There is growing attention to STEM education in Mainland China, especially because of the global advancement of technology. The need for more skilled and highly capable teachers of STEM Education therefore increases. However, there is not enough research to investigate the level of in-service teachers' STEM competence in Mainland China. Therefore, this study employed a survey method to examine the perceived competency of 66 in-service teachers in implementing STEM education in a nationwide middle school STEM education pilot in Mainland China. The adopted questionnaire is based on the four-dimensional Technological Pedagogical STEM Knowledge Survey (TP-STEMK). Descriptive analysis and T-tests were used for quantitative data. The results of the study indicated that the science-related dimension score was higher. However, engineering-related dimensions and the ability to integrate the former 3 factors were relatively lower. These teachers have a relatively higher self-perceived STEM competence than the median but lower than the whole average competence of STEM teachers in Mainland China according to the previous study, and besides that, there was no statistically significant difference in the scores according to gender.**

***Keywords*—teachers' perceived competence, STEM education, technological pedagogical STEM knowledge, gender difference**

I. INTRODUCTION

Many researchers are already focusing on teachers' perceived competence in implementing STEM education from general or specific single subjects, for example, Chai *et al.* [1]. However, most of these studies adopted surveys adapted from science-specific or general scales not specially created for the STEM education field. Some of these questionnaires were adapted from self-constructed scales [2] which do not have a strong theoretical ground. Unlike these studies, this study tried to assess in-service teachers' perceived competence to implement STEM education by considering the combination of pedagogical and technological factors with subjects and investigating the possible gender differences in STEM competence. So, the Technological Pedagogical STEM Knowledge (TP-STEMK) questionnaire combining the STEM subjects and technological pedagogical content knowledge (TPACK) model [3] was adopted in this study.

II. LITERATURE REVIEW

A. *Theoretical Framework: Technological Pedagogical STEM Knowledge (TP-STEMK)*

Chai *et al.* [3] developed the technological pedagogical STEM knowledge questionnaire (TP-STEMK) based on the TPACK theory. With high relevance, the instrument was adopted in this research. As shown in Fig. 1, the framework incorporates 4 dimensions, of which 3 dimensions are related to STEM knowledge: 1) knowledge of technological pedagogical mathematics (TPMK), 2) knowledge of technological pedagogical engineering (TPEK), and 3) knowledge of technological pedagogical science (TPSK). The fourth dimension represents the ability to integrate the former 3 factors called integrated STEM (iSTEM). The TPMK, TPEK, and TPSK are distinguished by the role of the technology they used: Mathematics uses technology focused on numerical data collection, calculating and modelling; engineering uses technology to emphasize the presentation of questions and solutions as a tool to aid the design; science with technology is to search and organize information [3]. Based on teacher efficacy studies and the TPACK framework literature [4], TPACK is a seven-factor model, and it considers each key subject in the STEM field. Seven factors seem too many to be measured in the research, so TP-STEMK with four factors is more appropriate and thus applied in this study. This model reflects the new standard of professional knowledge for teachers in the twenty-first century [3]. This survey scale had been tested in limited research and found valid and reliable in investigating the perceived competence of teachers' implementing STEM education in pre-and in-service mathematics, science, and technology teachers in Mainland China and Turkey [3, 5, 6]. The significance of TP-STEMK lies in the integration of technology, pedagogy, and content knowledge. This model is the first tool particularly designed for STEM Education. There is not much research using this tool to investigate teachers'

Manuscript received August 17, 2023; revised September 12, 2023; accepted December 15, 2023; published May 17, 2024.

STEM competence, so this study could contribute to this field.

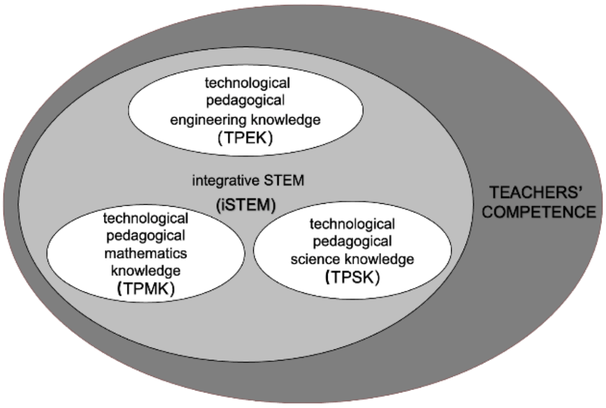

Fig. 1. This study's theoretical framework: Teachers' perceived competency in implementing STEM education.

B. Teachers' Perceived Competence

Teachers' perceived competence indicates the perceived ability in in-class teaching and the capability of fixing various teaching problems. Teachers' competence is the knowledge and skills which make teachers successful. Teachers' teaching competence is important for students' achievements and especially, teaching quality is vital for students' learning [7] and students' success is significantly influenced by teachers' professional knowledge and pedagogical expertise [8]. So, teachers with low capacity could not meet the real needs of students. From this view, investigating the teachers' competence in STEM education is necessary for students' STEM learning. Among various aspects of teachers' competence, Information Communication Technology (ICT) competence is considered an important component for future teachers [9] and pedagogical competencies are key to effective education [10]. When teaching ability is not directly measured, perceived teaching ability is a reasonable alternative. Although there is a gap between perceived competence and real competence, teachers' perceived competence is a legitimate and formative estimate of teachers' real competence [11]. Besides, evidence has shown that perceived competence in skills in design and teaching is mostly close to teachers' real teaching competence [12].

C. Gender Differences and Teachers' Competency

The number of female teachers is usually higher than that of male teachers in children's education. Taking information technology which is one more the core disciplines of STEM education as an example. Studies have shown that there is no gender difference in information technologies knowledge teaching capacity [13]. However, other research showed the opposite view that there is an existing significant difference in gender in information technologies competence among teachers [14]. Although there are many studies on the ability difference between male and female teachers, there is little research on the influence of gender differences on teaching ability in STEM fields. Therefore, it is worth paying attention to whether there is any difference between female teachers' abilities and male teachers' abilities in STEM teaching.

III. MATERIALS AND METHODS

There were 66 teachers from this pilot middle school of STEM education in Inner Mongolia in Mainland China as the participants in this study, which used a survey research design.

A. Research Questions

Considering the investigation of teachers' perceived competence in conducting STEM education in Mainland China is limited as there are only a few researches such kind of the study by Dong *et al.* [15], Song and Zhou [16], and responding to the new requirements for 21st-century teachers, we should first consider the state of teachers' competency in STEM education. The following are the study's research questions:

(1) How do teachers perceive their competence in implementing STEM education in a pilot middle school of STEM education?

(2) Are there differences among the teachers' competence scores in TPSK, TPMK, TPEK, and iSTEM arising from gender?

B. Research Method and Data Analysis

Due to resource constraints, this study only included 66 math, science, and technology teachers from a STEM pilot middle school in Mainland China. In this study, a survey method was used, as illustrated in Fig. 2. The process of data access is as follows: Firstly, 66 science, math and technology teachers were invited through random sampling in a pilot middle school in Mainland China to finish a TP-STEMK questionnaire [3] with a 7-point Likert scale (strongly disagree-1, disagree-2, somewhat disagree-3, unsure-4, somewhat agree-5, agree-6, and strongly agree-7). After quantitative data collection, descriptive analysis and T-test analysis were adopted to draw a conclusion.

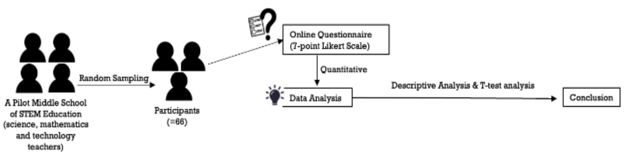

Fig. 2. Entire research design.

C. Quantitative Approach: Chai et al.'s Questionnaire on Teachers' Perceived Competence in Implementing STEM Education

The TPEK, TPMK, TPSK, and iSTEM components of teachers' competency were assessed by using a 7-point Likert scale questionnaire. This survey scale includes 5 items for TPMK and 4 items for the each of rest of the perceived competence, which is in total 17 items. To better suit the language of teachers in Mainland China, the questionnaire was translated into Chinese when collecting data.

IV. Result and Findings

A total of 71 questionnaires were collected, of which 66 were valid questionnaires, and 5 were invalid questionnaires because those teachers did not have STEM education experience and therefore were not regarded as teachers of STEM education.

A. Background of Participants

Table I shows the background of the participants in this study. Among them are 41 female teachers (62.12%) and 25 male teachers (37.88%). Among the teachers participating in the research, the number of teachers with a scientific background is the largest, with a total of 39 (59.09%), followed by mathematics, with 26, accounting for 39.39%, and the last is technology teachers, with 2 teachers. From the perspective of teaching age, most of the teachers have more than 10 years of teaching experience (27 participants), and the number of teachers with 3–5 years of teaching experience is the least, with a total of 8 people.

TABLE I. The Characteristics of the Participants

	Teachers	Frequency	Percentage
Gender	Woman	41	62.12%
	Man	25	37.88%
Branch	Science	39	59.09%
	Math	26	39.39%
	Technology	2	3.03%
	Others	0	0
Teaching age	Less than 3 years	19	29%
	3–5 years	8	12.12%
	6–10 years	12	18.18%
	More than 10 years	27	40.91%
Total	Teachers	66	

B. Research Question 1: Teachers' Perceived Competence in Implementing STEM Education

TABLE II. Results of Teachers' Perceived Competence in STEM Education

Dimension	Mean Score
Technological pedagogical science knowledge (TPSK)	5.11
Technological pedagogical mathematics knowledge (TPMK)	4.91
Technological pedagogical engineering knowledge (TPEK)	4.25
Integrative STEM (iSTEM)	4.34
Overall average score	4.6525

As shown in Table II, the results of the questionnaire show that the average score of the four dimensions of STEM teachers' perceptual ability is: 5.11 in TPSK, 4.91 in TPMK, 4.25 in TPEK and 4.34 in iSTEM. In other words, their knowledge of technological pedagogical science was especially higher. This may imply that teachers have more confidence in the science domain when implementing STEM education. However, their knowledge of technological pedagogical engineering and the ability to integrate the former 3 factors were relatively lower. To sum up, the overall average score is about 4.6525 which is higher than the median number (3.5) of a total 7-point scale, but lower than the average score in Chai *et al.* [3]'s paper (5.1225), which investigated the average STEM competence of teachers in Mainland China, indicating that the teachers in this school generally have relatively lower self-perceived STEM teaching ability.

C. Research Question 2: Gender Differences in Subfactors of TP-STEMK

As stated, besides investigating teachers' perceived competence in implementing STEM education in a pilot middle school of STEM education, this study also investigated whether there are possible differences arising from gender. Tables III and IV show that there is no statistical difference between teachers' overall scores and gender, where $P = 0.156$ and $t(64) = -0.25$. There is also no statistical gender difference in the four dimensions of TP-STEMK, as for the iSTEM dimension, $P = 0.054$, $t(64) = -0.428$, and for TPEK, $P = 0.228$, $t(64) = 0.301$, and for TPMK, $P = 0.599$, $t(64) = -0.15$, and for TPSK, $P = 0.487$ and $t(64) = -0.694$. Also, it is showed females have a little higher competence than males in terms of average scores. Nevertheless, regarding their ability to integrate the former 3 factors, the result is close to significant ($p = 0.054$) and this phenomenon seems worth further study. Supplementary information can be found in Fig. 3.

TABLE III. Teachers' Scores of Self-Perceived Teachers' Competencies by Gender

Gender	Mean score
Female	4.7
Male	4.62

TABLE IV. T-Test Results of Teachers' Total Scores, iSTEM, TPEK, TPMK, and TPSK Scores by Gender

	F	p	t	df
Total Score	2.056	0.156	−0.25	64
iSTEM	3.843	0.054	−0.428	64
TPEK	1.48	0.228	0.301	64
TPMK	0.279	0.599	−0.15	64
TPSK	0.49	0.487	−0.694	64

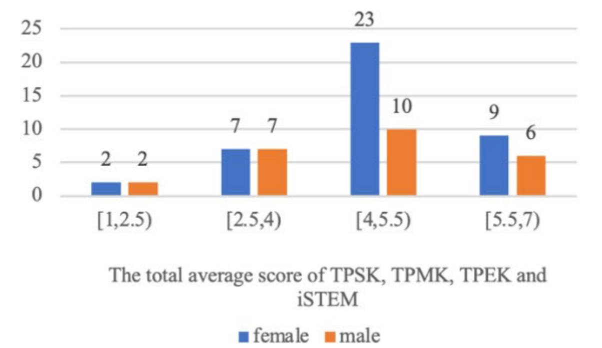

Fig. 3. Bar chart of total average score scores by gender and score range.

V. Discussion

In our study, we investigated teachers' perceived STEM competence. The findings could provide some evidence for the average pioneer STEM teacher's competence in economically underdeveloped areas in northern China and could give insight into future STEM teachers' education.

A. Teachers Perceived Competence in STEM Education

According to Güngör and Mücahit [5]'s research using the TP-STEMK questionnaire, teachers' scores in TPEK and iSTEM are the lowest. This result is very similar to those of this study, in which teachers' self-perception ability is the highest in TPSK, with an average score of 5.11, followed by TPMK, iSTEM, and TPEK scores are 4.91, 4.34, 4.25, respectively. This result is similar to the previous study [3], which also shows that STEM teachers lack engineering technological knowledge in the research, but the specific scores for each item were lower than those in Chai *et al.* [3]'s paper, 5.36 (TPSK), 5.16 (TPMK), 5.05 (TPEK), 4.92 (iSTEM), suggesting that this school's teachers' STEM skills were below the national average for STEM teachers. At the same time, the standard deviation of scores of teachers in this school for each dimension is higher than the corresponding standard deviation value in Chai *et al.* [3]'s paper, which indicates that teachers in this school have great differences in STEM perception ability, which may be one of the reasons for the low average score. Nevertheless, it still shows that teachers in this school generally have a relatively higher level of perceptual STEM teaching ability than the median 3.5. There are no significant differences by gender, which is the same as the research result from Chai *et al.* [3].

(1) Technological Pedagogical Science Knowledge (TPSK) Dimension

Among the four dimensions, the teachers have the highest level of TPSK. This may be related to the subject background of the participants (see Table I), and more than half of the STEM teachers have a science background: the number of teachers with a scientific background is the largest, with a total of 39 (59.09%). Thus, they may have been exposed to TPSK-related content during university study and then have the highest score in this item. This also shows that in this school, teachers have higher confidence in coping with science-related issues when implementing STEM education, which is also consistent with Postareff and Lindblom-Ylänne [17]'s research, which means that teachers are more confident in their own teaching in the field.

(2) Technological Pedagogical Mathematics Knowledge (TPMK) Dimension

In the TPMK dimension, teachers' self-perception of teachers' competence is weaker than that of TPSK but generally relatively high. The main reason may be that although there are fewer math teachers than scientific teachers (see Table I), almost all of them have a certain mathematic foundation and thus TPMK's ability is relatively higher among the four dimensions.

(3) Technological Pedagogical Engineering Knowledge (TPEK) Dimension

It is worth noting that teachers' iSTEM scores are higher than TPEK scores in this study, and TPEK scores are the lowest. This means that the teachers at this school generally perceive that they have the worst ability in the field of engineering. The possible reason is that in mainland China, especially in remote places, such as Inner Mongolia, junior high school teachers have the least opportunity to conduct engineering-related courses, and teachers are more familiar with basic subjects such as mathematics and physics. Another reason may be that the total number of teachers participating in the questionnaire is not large enough, and the results have certain deviations. Therefore, it is very important for schoolteachers to cultivate their ability in the TPEK field. Obviously, teachers generally lack relevant engineering design background and experience. Only by strengthening their own engineering design knowledge can teachers improve their ability, so, partnering with an engineering program or teachers of engineering majors in the future can be considered. There are already relevant cases In the West that combine engineering and STEM, for example, the case implemented by Burrows *et al.* [18], while China generally lacks such practices nowadays.

(4) Integrative STEM (iSTEM) Dimension

In the iSTEM dimension, the teacher' scores are relatively weaker among the four dimensions, but they are still higher than the median of 3.5. It shows that teachers' ability to integrate the former 3 factors was relatively lower even though this is key for effective implementing effective STEM education. Nevertheless, this is a common phenomenon in a school in the early period of implementing STEM education [19].

VI. Conclusion

A. Summary

This study investigated the STEM self-perception ability of teachers in a national STEM education demonstration school in Inner Mongolia, by examining four dimensions: TPSK, TPMK, TPEK, and iSTEM. By using the questionnaire of Chai *et al.* [3] to investigate these four aspects, the teachers at this school have the highest results in TPSK self-perception ability (average 5.11), followed by TPMK (average 4.91), then iSTEM (average 4.34), and finally TPEK (average 4.25), which answered the first research question, these teachers have a relative higher competence in STEM Education than the medium 3.5 but lower than the average score of teachers in Mainland China by Chai *et al.* [3]. And these findings are generally consistent with previous research as stated in the discussion part. For the second research question, although this sample, showed females have a little higher competence than males, there are no significant statistical differences in overall all 4 dimensions of TP-STEMK.

Little literature about perceived competence focused on engineering design and technological pedagogical knowledge is important for 21st-century education, especially in Mainland China. There is little research focused on gender differences in the STEM education field. All these show that this study could contribute to this area and provide evidence for future STEM teacher education studies.

B. Limitation and Implications for Future Study

There were certain limitations in this study. Although teachers' ability score is relatively higher than the median of 3.5, these figures could only represent the pioneer STEM teachers' STEM competence in economically underdeveloped areas in north China, so, more research needed to be conducted to collect more data for ordinary teachers in Mainland China to figure out the real level of STEM competence of teachers and the sample size is small, only a STEM pilot middle school in Inner Mongolia was sampled. It is suggested that a larger sample could be drawn in the future, and teachers could be randomly selected from different cities for STEM perception ability so that the results are more representative. In the future, some open-ended instruments could be developed to comprehensively evaluate teachers' knowledge in TP-STEM and one-on-one interviews also can be used to qualitatively investigate teachers' understanding of STEM education and self-assessment of their ability to implement STEM education to find out their difficulties and challenges in implementing STEM education, and therefore explain the reasons for the low score in the questionnaire, especially in TPEK. Nevertheless, this study adopted a TP-STEMK survey and collected the questionnaire data of STEM teachers in remote areas in Mainland China, making a certain contribution to future research in teacher education.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Liao Chunyang is responsible for conducting experimental research, reviewing literature, collecting data, analyzing data, writing papers, etc. Alex provides suggestions for the paper and modifiable the paper. All authors had approved the final version.

Acknowledgment

We sincerely thank the individuals and the middle school in this study.

References

[1] C. S. Chai, E. M. Ng, W. Li, *et al.*, "Validating and modelling technological pedagogical content knowledge framework among Asian preservice teachers," *Australasian Journal of Educational Technology*, vol. 29, Jan. 2013. https://doi.org/10.14742/ajet.174

[2] M. Song, "Integrated STEM teaching competencies and performances as perceived by secondary teachers in South Korea," *International Journal of Comparative Education and Development*, vol. 22, no. 2, 2020. https://doi.org/10.1108/ijced-02-2019-0016

[3] C. S. Chai, M. Jong, H. Yin, *et al.*, "Validating and modelling teachers' technological pedagogical content knowledge for integrative science, technology, engineering and Mathematics education," *Journal of Educational Technology & Society*, vol. 22, pp. 61–73, Mar. 2019.

[4] M. Koehler and P. Mishra, "What is technological pedagogical content knowledge (TPACK)?" *Contemporary Issues in Technology and Teacher Education*, vol. 9, no. 1, pp. 60–70, Mar. 2009.

[5] A. Güngör and K. Mücahit, "Adapting the survey of technological pedagogical STEM knowledge to the Turkish language and determining the knowledge of pre-service and in-service teachers," *International Journal of Modern Education Studies*, vol. 6, no. 2, pp. 287–318, 2022.

[6] M. J. N. Nalipay, M. S. Y. Jong, T. K. Chiu, *et al.*, "Teachers' technological pedagogical content knowledge for integrative science, technology, engineering, and mathematics education," in *Proc. International Symposium on Educational Technology (ISET)*, July 2022, pp. 37–41. https://doi.org/10.1109/iset55194.2022.00016

[7] L. Darling-Hammond, "Teacher quality and student achievement," *Education Policy Analysis Archives*, vol. 8, no. 1, Jan. 2000. https://doi.org/10.14507/epaa.v8n1.2000

[8] J. Baumert, M. Kunter, W. Blum, *et al.*, "Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress," *American Educational Research Journal*, vol. 47, no. 1, pp. 133–180, 2010. https://doi.org/10.3102/0002831209345157

[9] P. Peciuliauskiene and M. Barkauskaite, "Would-be teachers' competence in applying ICT: Exposition and preconditions for development," *Informatics in Education*, vol. 6, no. 2, pp. 397–410, 2007. https://doi.org/10.15388/infedu.2007.26

[10] A. I. Suciu and L. Mata, "Pedagogical competences – The key to efficient education," *International Online Journal of Educational Sciences*, vol. 3, no. 2, pp. 411–423, 2011.

[11] S. Borg and A. Edmett, "Developing a self-assessment tool for English language teachers," *Language Teaching Research*, vol. 23, no. 5, pp. 655–679, 2019. https://doi.org/10.1177/1362168817752543

[12] H. J. Kim, "Exploring pre-service teachers' beliefs about English teaching competence, perceived competence, and actual competence," *Journal of Pan-Pacific Association of Applied Linguistics*, vol. 23, no. 2, pp. 1–19, 2019. https://doi.org/10.25256/paal.23.2.1

[13] J. S. Prieto, J. M. T. Torres, M. G. García, *et al.*, "Gender and digital teaching competence in dual vocational education and training," *Education Sciences*, vol. 10, no. 3 p. 84, 2020. https://doi.org/10.3390/educsci10030084

[14] Y. Zhao, A. M. P. Llorente, M. C. S. Gómez, *et al.*, "The impact of gender and years of teaching experience on college teachers' digital competence: An empirical study on teachers in Gansu Agricultural University," *Sustainability*, vol. 13, no. 8, April 2021. https://doi.org/10.3390/su13084163

[15] Y. Dong, J. Wang, Y. Yang, *et al.*, "Understanding intrinsic challenges to STEM instructional practices for Chinese teachers based on their beliefs and knowledge base," *International Journal of STEM Education*, vol. 7, no. 1, pp. 1–12, 2020. https://doi.org/10.1186/s40594-020-00245-0

[16] H. Song and M. Zhou, "STEM teachers' preparation, teaching beliefs, and perceived teaching competence: A multigroup structural equation approach," *Journal of Science Education and Technology*, vol. 30, no. 3, pp. 394–407, 2021. https://doi.org/10.1007/s10956-020-09881-1

[17] L. Postareff and S. Lindblom-Ylänne, "Emotions and confidence within teaching in higher education," *Studies in Higher education*, vol. 36, no. 7, pp. 799–813, 2011. https://doi.org/10.1080/03075079.2010.483279

[18] A. Burrows, M. Lockwood, M. Borowczak, *et al.*, "Integrated STEM: Focus on informal education and community collaboration through engineering," *Education Sciences*, vol. 8, no. 1, p. 4, 2018. https://doi.org/10.3390/educsci8010004

[19] M. Honey, G. Pearson, and H. Schweingruber, "A descriptive framework for integrated STEM education," in *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*, Washington, DC: National Academies Press, 2014, ch. 2, pp. 31–50.