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# EXPLORANDO O CONHECIMENTO DO CONTEÚDO PEDAGÓGICO MATEMÁTICO DE PROFESSORES EM FORMAÇÃO

M-PCK DE PROFESSORES PRÉ-SERVIÇO

*EXPLORING MATHEMATICAL PEDAGOGICAL CONTENT KNOWLEDGE OF PRE-SERVICE TEACHERS*

*Pre-service teachers' M-PCK*

*EXPLORANDO EL CONOCIMIENTO DEL CONTENIDO PEDAGÓGICO MATEMÁTICO DE LOS FUTUROS MAESTROS*

*M-PCK de futuros maestros*

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## RESUMO

O objetivo deste estudo transversal foi examinar as percepções dos licenciandos sobre seu conhecimento de conteúdo pedagógico matemático e determinar o efeito de variáveis demográficas (gênero, grau de escolaridade) em seu conhecimento de conteúdo pedagógico matemático. Um questionário de escala Likert foi usado para coletar dados de 104 licenciandos. A estatística descritiva e o teste U de Mann-Whitney foram usados para examinar o conhecimento percebido dos licenciandos sobre estratégias de ensino, linguagem e os símbolos matemáticos, sobre o erro (equívocos), o currículo e seu conhecimento percebido dos alunos. Os resultados mostram que, em geral, a maioria dos licenciandos tem maior percepção do seu conhecimento do conteúdo pedagógico matemático. Eles consideram o planejamento de aulas, o propósito do currículo de matemática e as ferramentas de avaliação usadas em uma sala de aula de matemática como aspectos importantes de seu conhecimento percebido do currículo. Também foi identificado que seu conhecimento percebido de equívocos os capacitaria a conhecer e antecipar os equívocos de seus alunos. No entanto, os resultados também indicaram que não houve diferença estatisticamente significativa no conhecimento do conteúdo pedagógico matemático dos

licenciandos com base no gênero e no grau de escolaridade. Implicações do estudo também são discutidas.

Palavras-chave: licenciandos. conhecimento pedagógico do conteúdo. matemática.

## ABSTRACT

The purpose of this cross-sectional study was to examine pre-service teachers' perceptions of their mathematical pedagogical content knowledge and to determine effect of demographic variables (Gender, year of study) on their mathematical pedagogical content knowledge. A Likert scale questionnaire was used to collect data from 104 pre-service teachers. Descriptive statistics and Mann-Whitney U-test were used to examine pre-service teachers' perceived knowledge of teaching strategies, mathematical language and symbols, misconceptions, curriculum, and their perceived knowledge of learners. Results show that in general, majority pre-service teachers have strong perceptions of their mathematical pedagogical content knowledge. They consider lesson planning, purpose of the mathematics curriculum and assessment tools used in a mathematics classroom as important aspects of their perceived knowledge of the curriculum. It was also revealed that their perceived knowledge of misconception would enable them to know and anticipate their learners' misconceptions. However, results also indicated that there was no statistically significant difference in pre-service teachers' mathematical pedagogical content knowledge based on gender and year of study. Study implications are also discussed.

Keywords: pre-service teachers. pedagogical content knowledge. mathematics.

## RESUMEN

El propósito de este estudio transversal fue examinar las percepciones de futuros docentes sobre su conocimiento del contenido pedagógico matemático y determinar el efecto de las variables demográficas (género, grado de escolarización) en su conocimiento del contenido pedagógico matemático. Se utilizó un cuestionario de escala Likert para recopilar datos de 104 futuros profesores. Se utilizaron estadísticas descriptivas y la prueba U de Mann-Whitney para examinar el conocimiento percibido de los maestros en formación sobre estrategias de enseñanza, lenguaje y símbolos matemáticos, e también para examinar conceptos erróneos, el currículo y la decepciones los professores sobre el conocimiento percibido de los estudiantes. Los resultados muestran que, en general, la mayoría de los futuros docentes tienen una buena percepción con relación a su conocimiento del contenido pedagógico matemático. Consideran la planificación de las clases, el propósito del currículo de matemáticas y las herramientas de evaluación utilizadas en un salón de clases de matemáticas como aspectos importantes de su conocimiento sobre el currículo. También se reveló que su conocimiento percibido de conceptos erróneos les permitiría conocer y anticipar los conceptos erróneos de sus alumnos. Sin embargo, los resultados también indicaron que no hubo una diferencia estadísticamente significativa en el conocimiento del contenido pedagógico matemático de los futuros maestros en función del género y grado de escolaridad. También se discuten las implicaciones del estudio.

Palabras clave: futuros docentes. conocimiento del contenido pedagógico. matemáticas.

## Introduction

Teachers' pedagogical content knowledge (PCK) is important if teaching and learning has to improve (Kadarisma et al., 2019; Sintema & Marban, 2020). For mathematics teachers, mathematical pedagogical content knowledge (M-PCK), which refers to subject (*mathematics*) specific PCK, plays a central role

in modelling every teacher's classroom practice (Gasteiger et al., 2020; Neudbrand, 2018). It enables teachers to develop in-depth "understanding of what makes the learning of specific [mathematics] concepts easy or difficult: the (*mis*)conceptions and preconceptions that students of different backgrounds bring with them to the mathematics classroom" (Shulman, 1986, p. 9).

To develop PCK as conceptualized by Shulman (1986) and to emphasise the concept of M-PCK, Ball et al. (2008) developed the mathematical knowledge for teaching in which they discussed and distinguished teachers' knowledge of *mathematics* content and learners from teachers' knowledge of *mathematics* content and teaching. The former refers to teachers' special knowledge of students' pre-requisite mathematical knowledge and potential challenges they are expected of because of new concepts to be learnt. On the other hand, the latter refers to teachers' knowledge different ways of "representing and formulating the subject *[mathematics]* that makes it comprehensible to others *[learners]*" (Shulman, 1986, p. 9). By this, Ball et al. (2008) and Shulman (1986). This implies that teachers would require high knowledge of different teaching strategies and ability to innovatively select suitable strategies for teaching specific mathematical content.

It is thus important to understand teachers' own awareness of their M-PCK. This because their perception of students' mathematical difficulties would determine the extent to which they can help their students overcome these difficulties (Gasteiger et al., 2020; Rahman et al., 2022). Similarly, Teachers' perception of teaching approaches and strategies would determine their ability to choose strategies that can help then effectively deliver mathematical concepts to their students. Thus, the purpose of this study is to explore pre-service teachers' (PSTs) M-PCK and whether their M-PCK significantly differs based on their gender and year of study. Several studies have been conducted on teachers' PCK of mathematics but not much has been investigated on the M-PCK perceptions of PSTs considering that these are the future classroom teachers. This study will contribute to the literature on PSTs' self-reported perceived M-PCK.

## Pedagogical content knowledge for mathematics teachers

Scholars have argued that PCK is useful at two important stages in the teaching and learning process (Alonso & Kim, 2015; Baki & Arslan, 2022). For example, Baki and Arslan, (2022) describe M-PCK in terms of *knowledge of students* (teacher's lesson planning be based on students' prior knowledge, understanding, misconceptions and beliefs), *lesson preparation and delivery* (to emphasise explanations, examples, analogies and representations). They also described it in terms of *assessment and evaluation* (to reflect on content to be learned and reasons for learning, which lesson objectives were achieved, content to be covered in the next lesson). According to Alonso and Kim (2015), teachers use PCK when they are planning for their lessons (declarative PCK) and during the time that they implement the planned activities in class (dynamic PCK). Thus, PSTs are expected to develop strong declarative PCK and dynamic PCK for them to teach effectively in their future classrooms. To do so, PSTs are expected to possess strong knowledge of mathematics subject matter as well as knowledge of principles that govern mathematics instruction (Cinar et al., 2016; Depaepe et al., 2013).

PSTs' potential to effectively teach mathematical concepts in their classrooms is highly dependent on their PCK (Aydin-Gunbatar et al., 2020; Baki & Arslan, 2022; Rahman et al., 2021a, 2021b). PSTs require sufficient PCK to adequately understand the mathematics curriculum, formulate measurable objectives and design lesson plans that maximise student participation in the planed classroom activities (Attard et al., 2020; Faikhamta et al., 2020; Rahman et al., 2021a; Song, 2019; Vossen et al., 2019). Several other studies have been carried out on PSTs' M-PCK (Cheryan et al., 2017; Danisman & Tanisli, 2017; Depaepe et al., 2015; Lee et al., 2018; Rahman et al., 2022; Trobst et al., 2019) with mixed results. For example, some researchers (Depaepe et al., 2015; Trobst et al., 2019) found high M-PCK levels among participants while others (Danisman & Tanisli, 2017; Lee et al., 2018) reported low M-PCK in the participants of their studies. In addition, other studies (Cheryan et al., 2017; Rahman et al., 2022) reported that demographic variables like gender did not influence PSTs' M-PCK. Considering the importance of demographic variables in understanding teachers' perceptions, we decided to investigate

the effect of gender and year of study on Zambian PSTs. This would contribute contextual perspectives to the literature vis-a-vis the Zambian context. Thus, our study sought answers to the following questions:

1. What are secondary pre-service mathematics teachers' M-PCK perceptions?

2. To what extent do secondary pre-service mathematics teachers' M-PCK perceptions differ when analysed based on demographic variables (gender and year of study)?

## Methodology

To adequately explore and have a wide understanding of PSTs' M-PCK perceptions, the current study employed the survey research design (Gable, 1994; Nardi, 2018). Participants of the study were drawn from 3rd and 4th year students pursuing a 4-year bachelor's degree at two public universities in Zambia using the cluster sampling technique (c.f Sharma, 2017). Both university follow a similar model of mathematics teacher education. In this model, the Department(s) of Mathematics Education only offers pedagogical courses to its PSTs. PSTs register for mathematics content courses in the Department(s) of Mathematics. The universities have no control over gender balance among its students, as every student is free to enrol in a study program of their choice. Cluster sampling has the advantage of selecting subjects that fragmented and occur naturally in their settings, in our case, universities (Acharya et al., 2013; Sharma, 2017). The sample comprised of more male students which speaks to the high enrolment of males in the Bachelor of Science with education (BSc.Ed) program. Considering that participation was voluntary, more 3rd year students (55.8%) volunteered to participate in this study. The sample was dominated by male participants (75%) and half of participants were aged 24 - 26 years old. All these demographic characteristics of participants are presented in Table 1.

Table 1. Demographic profiles of PSTs

| Characteristic | | N | % |
|---|---|---|---|
| Age | 27 years and older | 16 | 15.4 |
| | 24-26 years old | 52 | 50 |
| | 20-23 years old | 36 | 34.6 |
| Gender | Male | 78 | 75 |
| | Female | 26 | 25 |
| Year of study | 3rd year | 58 | 55.8 |
| | 4th year | 46 | 44.2 |

Data were collected using a 17-item self-administered M-PCK perceptions questionnaire adapted from Bukova-Guzel et al. (2013). The items were spread across five constructs: knowledge of teaching strategies (KTS) with 3 items, knowledge of mathematical language and symbols (KMLS) with 2 items, knowledge of misconceptions (KM) with 3 items, knowledge of learners (KL) with 2 items, and knowledge of curriculum (KC) with 7 items. We calculated the Cronbach's alpha reliability coefficient using our sample and found it to be 0.75 which is not good enough but acceptable (George & Mallery, 2003). Participants were requested to indicate their M-PCK perceptions by responding to the questionnaire using a 5-point Likert scale (1 = Never, 2 = rarely, 3 = Undecided, 4 = Usually, 5 = Always).

Data were analysed using the Statistical Package for Social Sciences (SPSS) Version 23. Three analyses were conducted in SPSS. First, we run descriptive statistics (i.e., frequencies, percentages, means, standard deviations) to establish PSTs' M-PCK perceptions (Research question 1). We then sought to examine the effect of gender and year of study on PSTs' M-PCK perceptions (Research question 2). We accomplished this by conducting a nonparametric statistical test: Mann-Whitney U-test.

**Results: Pre-service mathematics teachers' M-PCK perceptions**

PSTs' M-PCK perceptions were first analysed using descriptive statistics (see Table 2). Results of this analysis shows that PSTs possess high perceived M-PCK (see Table 2). This implies that they have high confidence in their teaching strategies as well as their ability to identify and solve problems related to learner's misconceptions. Additionally, these PSTs are highly confident that they would use correct mathematics languages and symbols in their future classrooms. Further, these PSTs are confident about their use of curriculum materials and understanding the demands of the mathematics curriculum. Table 2 shows mean scores and standard deviations the five M-PCK scales that speak to aspects of teaching strategies ($\mathrm{KTS}_{\mathrm{mean}} = 4.20$), mathematical language and symbols ($\mathrm{KMLS}_{\mathrm{mean}} = 4.49$), Misconceptions ($\mathrm{KM}_{\mathrm{mean}} = 4.16$), knowledge of learners ($\mathrm{KL}_{\mathrm{mean}} = 4.07$) and curriculum knowledge ($\mathrm{KC}_{\mathrm{mean}} = 4.25$).

Table 2. Descriptive statistics of pre-service teachers' M-PCK perceptions

| Knowledge domain | Mean | Std. Deviation |
|---|---|---|
| Knowledge of Teaching Strategies | 4.20 | .88 |
| Knowledge of Mathematical Language and Symbols | 4.49 | .67 |
| Knowledge of Misconceptions | 4.16 | .71 |
| Knowledge of Learners | 4.07 | .90 |
| Knowledge of Curriculum | 4.25 | .53 |

**Pre-service mathematics teachers' M-PCK perceptions based on their KTS**

PSTs' perceptions of their KTS were defined by 3 items (see table 3). It is clear from Table 3 that majority of PSTs that participated in this study perceived mathematics as being closely related to the day-to-day lives of humans. It is the perception of majority PSTs (52.9%) that they can always relate concepts in mathematics to day-to-day real life situation during classroom instruction. Additionally, 33.7% perceived themselves as teachers who would usually relate mathematical concepts to real life situations. Surprisingly, 5.8% of the PSTs indicated that they can never use analogies when teaching mathematics while 2.9% said that they can never design appropriate activities to teach mathematics in their classrooms. Quite a large number (25%) of PSTs were not sure about their use of analogies in explaining mathematical concepts in their classrooms.

Table 3. Pre-service Teachers' Perceived Knowledge of Teaching Strategies (KTS)

| | Never | | Rarely | | Undecided | | Usually | | Always | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F | % | F | % | F | % | F | % | F | % |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| I can design appropriate activities to present mathematical concepts | 3 | 2.9 | 11 | 10.6 | 1 | 1 | 40 | 38.5 | 49 | 47.1 |
| I can relate mathematical concepts to daily life in instruction | 0 | 0 | 12 | 11.5 | 2 | 1.9 | 35 | 33.7 | 55 | 52.9 |
| I can use analogies to mathematical concepts in instruction | 2 | 5.8 | 31 | 29.8 | 25 | 24 | 29 | 27.9 | 13 | 12.5 |

**Pre-service mathematics teachers' M-PCK perceptions based on their KMLS**

According to responses displayed in Table 4, PSTs generally showed high perceptions of their KMLS. This was justified by the large number of PSTs (58.7%) who said that they would always and 33.7% who indicated that they would use proper and acceptable mathematical language when presenting mathematical concepts to their learners. Only 2.9% were not sure and 4.8% would rarely use appropriate mathematical language during instruction. On the other hand, most of the PSTs (60.6%) showed high perceptions of using appropriate and acceptable mathematical symbols during instruction. An additional 33.7% of PSTs perceived themselves teachers who would usually teach using appropriate mathematical symbols. However, a small number of PSTs (2.9%) reported that they were undecided on whether to use mathematical symbols or not while 4.8% said that they would rarely use mathematical symbols in class.

Table 4. PSTs' Perceived Knowledge of Mathematical Language and Symbols (KMLS)

| | Never | | Rarely | | Undecided | | Usually | | Always | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F | % | F | % | F | % | F | % | F | % |
| I can use mathematical language properly when presenting mathematical concepts | 0 | 0 | 5 | 4.8 | 3 | 2.9 | 35 | 33.7 | 61 | 58.7 |
| I can use mathematical symbols properly | 0 | 0 | 4 | 3.8 | 2 | 1.9 | 35 | 33.7 | 63 | 60.6 |

**Pre-service mathematics teachers' M-PCK perceptions based on their KM**

PSTs' perceptions of their knowledge of learners' misconceptions were defined by 3 items (Table 5). In relation to their ability to anticipate students' difficulties about a given mathematics topic, 88.5% of PSTs indicated that they can either always anticipate (45.2%) or usually anticipate (43.3%) possible students' difficulties about a given mathematics topic. It is rather surprising that some PSTs (2.9%) would never anticipate their students' difficulties in a mathematics topic. Interestingly, 43.3% of PSTs said that they would always design or select classroom activities that would not lead their students to develop misconceptions about a given mathematics topic. Similarly, 35.6% of PSTs reported that they were knowledgeable about their students' possible misconceptions about a given mathematics topic. Only 8.7% said they would rarely do that.

Table 5. PSTs' Perceived Knowledge of Misconceptions (KM)

| | Never | | Rarely | | Undecided | | Usually | | Always | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F | % | F | % | F | % | F | % | F | % |
| I can anticipate students' possible difficulties about a topic | 3 | 2.9 | 2 | 1.9 | 7 | 6.7 | 45 | 43.3 | 47 | 45.2 |
| I know students' possible misconceptions about a topic | 1 | 1 | 9 | 8.7 | 6 | 5.8 | 51 | 49 | 37 | 35.6 |
| I can design activities that will not cause students to develop misconceptions about the topic | 1 | 1 | 9 | 8.7 | 10 | 9.6 | 39 | 37.5 | 45 | 43.3 |

**Pre-service mathematics teachers' M-PCK perceptions based on their KL**

Table 6 shows PSTs' responses to items related to their perceptions of KL. Analysing Table 6, majority PSTs (47.1%) perceived themselves as usually being knowledgeable about their students' prior knowledge about a given mathematics topic while 37.5% said they would always know their students' prior knowledge of a mathematics topic. On the other hand, more than half of the PSTs (54.8%) indicated that they can choose appropriate examples for students' developmental levels in my lessons. This generally implies that PSTs had high perceptions of their KL.

Table 6. Pre-service Teachers' Perceived Knowledge of Learners (KL)

| | Never | | Rarely | | Undecided | | Usually | | Always | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F | % | F | % | F | % | F | % | F | % |
| I know students' prior knowledge about a topic | 2 | 1.9 | 8 | 7.7 | 6 | 5.8 | 49 | 47.1 | 39 | 37.5 |
| I can choose appropriate examples for students' developmental levels in my lessons | 0 | 0 | 6 | 5.8 | 2 | 1.9 | 39 | 37.5 | 57 | 54.8 |

**Pre-service mathematics teachers' M-PCK perceptions based on their KC**

PSTs' perceptions of their KC were defined by 7 items, the most of all compared to other knowledge constructs which were defined by not more than 3 items each. Examining Table 7, a general picture that emerges shows that pre-service teacher had high KC perceptions. For example, the item related to PSTs' knowledge of designing a lesson plan was the most outstanding with 72.1% of PSTs affirming they knowledge of lesson plan preparation. Similarly, the item related to PSTs' knowledge of linking goals of a given mathematics topic when designing a lesson plan was yet another outstanding one with 56.7% of PSTs indicating that they would always linking lesson plan design to goals of a mathematics topic. However, the item that related to PSTs' ability to use assessment tools from the mathematics curriculum

raised concern as 18.3% of PSTs reported that they can rarely use assessment tools from a mathematics curriculum.

Table 7. PSTs' Perceived Knowledge of Curriculum (KC)

| | Never | | Rarely | | Undecided | | Usually | | Always | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F | % | F | % | F | % | F | % | F | % |
| I have knowledge about the purposes of the mathematics curriculum | 1 | 1 | 10 | 9.6 | 5 | 4.8 | 38 | 36.5 | 50 | 48.1 |
| I can design a lesson plan for a topic | 1 | 1 | 3 | 2.9 | 4 | 3.8 | 21 | 20.2 | 75 | 72.1 |
| I plan my lessons so as to relate the purposes of the mathematics curriculum with students' needs | 1 | 1 | 8 | 7.7 | 4 | 3.8 | 42 | 40.4 | 49 | 47.1 |
| When designing my lesson plans, I consider the goals of the topic | 1 | 1 | 4 | 3.8 | 7 | 6.7 | 33 | 31.7 | 59 | 56.7 |
| I can use the assessment tools presented in the mathematics curriculum | 1 | 1 | 19 | 18.3 | 3 | 2,9 | 41 | 39.4 | 40 | 38.5 |
| I can evaluate the effectiveness of the activities I use in the class for students' conceptual understanding | 1 | 1 | 9 | 8.7 | 4 | 3.8 | 49 | 47.1 | 41 | 39.4 |
| I can draw on the results of my evaluations in designing and adjusting the instruction | 1 | 1 | 7 | 6.7 | 10 | 9.6 | 43 | 41.3 | 43 | 41.3 |

**Pre-service mathematics teachers' M-PCK perceptions based on gender and year of study**

To determine PSTs' differences in M-PCK perceptions based on their gender, we conducted the Mann-Whitney U-test (see Table 8). Results of the U-test showed that there were no significant difference between male and female PSTs' M-PCK perceptions ($U[N_{male} = 78, N_{female} = 26] = 928$, $z = -.65$, $p = .516$). This could further be confirmed by their median scores which are very close to each other for males ($Mdn_{male} = 4.33$) and females ($Mdn_{female} = 4.22$).

Table 8. Differences of secondary pre-service mathematics teachers' M-PCK perceptions based on gender

| Gender | N | Mean rank | Sum of ranks |
|---|---|---|---|
| Male | 78 | 53.61 | 4181.50 |

| | | | |
|---|---|---|---|
| Female | 26 | 49.17 | 1278.50 |

To determine PSTs' differences M-PCK perceptions based on their year of study, we conducted the Mann-Whitney U-test (see Table 9). Results of the U-test showed that there were no significant difference between third and fourth year PSTs' M-PCK perceptions ($U[N_{third\ year} = 58, N_{fourth\ year} = 46] = 1262$, $z = -.47$, $p = .637$). This could further be confirmed by their median scores which are very close to each other for males ($Mdn_{third\ year} = 4.27$) and females ($Mdn_{fourth\ year} = 4.31$).

Table 9. Differences of secondary pre-service mathematics teachers' M-PCK perceptions based on year of study

| Year of study | N | Mean rank | Sum of ranks |
|---|---|---|---|
| 3rd year | 58 | 51.26 | 2973 |
| 4th year | 46 | 54.07 | 2487 |

**Discussion and conclusion**

Generally, the M-PCK perceptions of the prospective teachers are strong. This implies that most of the PSTs in our study will have high confidence in the teaching competencies and will be aware of their students' mathematical needs and difficulties. This has implications for teacher training in Zambia. It means that teacher education programs for mathematics teachers support PSTs to develop their self-efficacy. This result is consistent with findings of Trobst et al. (2019) who found that participants in their study exhibited high levels of PCK. However, findings of this study are not consistent with those of Depaepe et al. (2015), whose study revealed gaps in teacher PCK and content knowledge. PSTs in our study were more confident of their perceptions of KMLS and KC perceptions than they were in other M-PCK sub-factors. This is a sign that they will be confident to handle and use the mathematics curriculum confidently and will also be able to teach using appropriate mathematical language. Results also indicate that PSTs are likely to be confident when selecting teaching strategies. In addition, they are also confidently deal with challenges in identifying their learners' misconceptions. PSTs of this study are confident that they will clearly understand demands of the mathematics curriculum.

The findings of this study are also not consistent with results of the study by Danisman and Tanisli (2017) whose study was aimed at determining high school mathematics teachers' PCK of probability. They investigated teachers' knowledge of content, knowledge of teaching methods and strategies, curriculum knowledge, and knowledge of their students. Results showed that secondary school mathematics teachers had insufficient PCK. Lee et al. (2018) also found low levels of PCK in their study. It was also found that PSTs' M-PCK did not statistically differ based on demographic variables (gender and year of study), similar to findings of Rahman et al. (2022). This implies that gender has no influence on PSTs' confidence in their M-PCK. Thus, male and female PSTs would equally succeed in developing their PCK for teaching mathematics with confidence (c.f. Attard et al., 2020; Cheryan et al., 2017; Rahman et al., 2022). This also implies that teacher educators are training teachers that are equally confident in the M-PCK.

As regards yeah of study, it is surprising that PSTs' M-PCK did not differ significantly. It was expected that PSTs in 4th year would exhibit higher M-PCK than those in 3rd year. The lack of difference does not imply that the teacher education program has no impact on PSTs. Rather it could be because most pedagogical courses are covered in the third year in these universities. It also implies that PSTs in 3rd and 4th year equally feel confident to teach mathematics. Teaching practice is mainly done in 3rd year and all participants had already experienced teaching in secondary school by the time of data collection.

Thus, the result could have been influenced by the fact that all participants had already completed similar pedagogical courses and a teaching practice experience. This result is consistent with findings of Rahman et al. (2022) who found that teaching experience did not have an effect on teachers' M-PCK.

## Limitations and recommendations for further studies

Lastly, this study had two major limitations that future studies should overcome. First, the questionnaire that was used contained 17 items to capture M-PCK perceptions where some M-PCK sub-factors like KMLS were composed of only two items. The small number of items per sub-factor were not sufficient to widely capture M-PCK perceptions of PSTs. Future users of the instrument we used should consider adding more items to comprehensively capture M-PCK perceptions. Second, our study was purely quantitative. Future researchers should consider mixed methodology to have in-depth understanding of PSTs' M-PCK perceptions by incorporating interviews or other qualitative techniques of collecting data. We also hope that future studies will consider having a larger sample than the one we used not only for validation of our study but for easy generalization of results.

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## References

Acharya, A. S., Prakash, A., Saxena, P., & Nigam, A. (2013). Sampling: Why and how of it. *Indian Journal of Medical Specialties*, *4*(2), 330-333.

Attard, C., Grootenboer, P., Attard, E., & Laird, A. (2020). Affect and engagement in STEM education. *STEM Education Across the Learning Continuum: Early Childhood to Senior Secondary*, 195-212. https://doi.org/10.1007/978-981-15-2821-7_11

Aydin-Gunbatar, S., Ekiz-Kiran, B., & Oztay, E. S. (2020). Pre-service chemistry teachers' pedagogical content knowledge for integrated STEM development with LESMeR model. *Chemistry Education Research and Practice*, *21*(4), 1063-1082. https://doi.org/10.1039/D0RP00074D

Baki, M., & Arslan, S. (2022). Impact of lesson study on pre-service primary teachers' mathematical pedagogical content knowledge. *International Journal of Mathematical Education in Science and Technology*, 1-19. https://doi.org/10.1080/0020739X.2021.2022225

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special?.

Bukova-Güzel, E., Cantürk-Günhan, B., Kula, S., Özgür, Z., & Elçí, A. N. (2013). Scale development for pre-service mathematics teachers' perceptions related to their pedagogical content knowledge. South African Journal of Education, 33(2), 1-21. https://doi.org/10.15700/saje.v33n2a690

Bukova-Güzel, E., Cantürk-Günhan, B., Kula, S., Özgür, Z., & Elçí, A. N. (2013). Scale development for pre-service mathematics teachers' perceptions related to their pedagogical content knowledge. South African Journal of Education, 33(2), 1-21. https://doi.org/10.15700/saje.v33n2a690

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others?. *Psychological bulletin*, *143*(1), 1. https://dx.doi.org/10.1037/bul0000052

Depaepe, F., Torbeyns, J., Vermeersch, N., Janssens, D., Janssen, R., Kelchtermans, G., ... & Van Dooren, W. (2015). Teachers' content and pedagogical content knowledge on rational numbers: A comparison of prospective elementary and lower secondary school teachers. Teaching and teacher education, 47, 82- 92. https://doi.org/10.1016/j.tate.2014.12.009

Faikhamta, C., Lertdechapat, K., & Prasoblarb, T. (2020). The impact of a PCK-based professional development program on science teachers' ability to teaching STEM. *Journal of Science and Mathematics Education in Southeast Asia*, *43*.

Gable, G. G. (1994). Integrating case study and survey research methods: an example in information systems. *European journal of information systems*, *3*(2), 112-126.

Gasteiger, H., Bruns, J., Benz, C., Brunner, E., & Sprenger, P. (2020). Mathematical pedagogical content knowledge of early childhood teachers: A standardized situation-related measurement approach. *ZDM*, *52*(2), 193-205. https://doi.org/10.1007/s11858-019-01103-2

George, D., & Mallery, P. (2019). IBM SPSS statistics 26 step by step: A simple guide and reference. Routledge.

Hughes, J. E. (2003). Toward a model of teachers' technology-learning. Action in teacher education, 24(4), 10- 17. https://doi.org/10.1080/01626620.2003.10463274

Kadarisma, G., Senjayawati, E., & Amelia, R. (2019). Pedagogical content knowledge pre-service mathematics teacher. In *Journal of Physics: Conference Series* (Vol. 1315, No. 1, p. 012068). IOP Publishing. https://doi.org/10.1088/1742-6596/1315/1/012068

Lee, Y., Capraro, R. M., & Capraro, M. M. (2018). Mathematics teachers' subject matter knowledge and pedagogical content knowledge in problem posing. International Electronic Journal of Mathematics Education, 13(2), 75- 90. https://doi.org/10.12973/iejme/2698

Nardi, P. M. (2018). *Doing survey research: A guide to quantitative methods*. Routledge.

Neubrand, M. (2018). Conceptualizations of professional knowledge for teachers of mathematics. *ZDM*, *50*(4), 601-612. https://doi.org/10.1007/s11858-017-0906-0

Rahman, N. A., Rosli, R., & Rambely, A. S. (2021b). Validating STEM pedagogical content knowledge scale for secondary school mathematics teachers. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(14), 3666-3678.

Rahman, N. A., Rosli, R., & Rambley, A. S. (2021a). Mathematical teachers' knowledge of STEM-based education. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012216). IOP Publishing. https://doi.org/10.1088/1742-6596/1/012216

Rahman, N. A., Rosli, R., Rambely, A. S., Siregar, N. C., Capraro, M. M., & Capraro, R. M. (2022). Secondary school teachers' perceptions of STEM pedagogical content knowledge. *Journal on Mathematics Education*, *13*(1), 119-134. http://doi.org/10.22342/jme.v13i1.pp119-134

Sharma, G. (2017). Pros and cons of different sampling techniques. *International journal of applied research*, *3*(7), 749-752.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher*, *15*(2), 4-14.

Sintema, E. J., & Marbán, J. M. (2020). Pre-service secondary teachers' mathematical pedagogical content knowledge self-concept related to their content knowledge of functions and

students. *International Electronic Journal of Mathematics Education*, *15*(3), em0598. https://doi.org/10.29333/iejme/8327

Song, M. (2020). Integrated STEM teaching competencies and performances as perceived by secondary teachers in South Korea. *International Journal of Comparative Education and Development*, *22*(2), 131-146. https://doi.org/10.1108/IJCED-02-2019-0016

Tröbst, S., Kleickmann, T., Depaepe, F., Heinze, A., & Kunter, M. (2019). Effects of instruction on pedagogical content knowledge about fractions in sixth-grade mathematics on content knowledge and pedagogical knowledge. Unterrichtswissenschaft, 47(1), 79-97. https://doi.org/10.1007/s42010-019-00041-y

Vossen, T. E., Henze, I., De Vries, M. J., & Van Driel, J. H. (2020). Finding the connection between research and design: the knowledge development of STEM teachers in a professional learning community. *International Journal of Technology and Design Education*, *30*, 295-320. https://doi.org/10.1007/s10798-019-09507-7