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A qualitative study of mathematical content knowledge and pedagogical content knowledge and self-perception in Moroccan context

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ABSTRACT

Pre-service teachers' (PSTs) tertiary training is essential to their development as competent educators and to their professional readiness. Teachers must acquire the ability to communicate mathematical material in a variety of ways. Teachers of excellence must be proficient in the relevant mathematics content knowledge (MCK) and possess a strong foundation in interacting successfully with students. This study on education has two objectives: looking into how secondary PSTs who take part in a mathematics teaching unit view themselves as they interact with and solidify their MCK, and investigating how these PSTs view and understand their "readiness" to take on such a task. 25 PSTs participating in postgraduate teacher preparation programs were given the pre-unit survey (Phase 1), whose answers were subject to an extensive analysis through a high level of evaluation using a framework assisting the researcher in identifying relationships among social phenomena, based on the similarities and differences that connect these phenomena. Self-reflections of participants revealed different levels of readiness to teach lower secondary students in mathematics. All participants emphasized the need to enhance their pedagogical content knowledge (PCK) and their MCK, and a very limited number of studied participants said they felt comfortable teaching mathematics. The study implies a significant issue with professional readiness and self-efficacy, and it recommends a need for earlier and more intensive practical experience integrated with strong mentorship. A number of implications for either policy or teacher training practice are proposed. This study will cover the main outcomes of Phase 1 in light of the body of current studies on preparing PSTs of mathematics.

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1. INTRODUCTION

Content knowledge (CK) includes knowledge related to a subject and its organizational structure [1] and refers to facts, concepts, theories, and principles [2]. A sign of CK mastery is being able to deepen particular elements through scientific mastery. A possible indication is that pre-service teachers' (PSTs) are proficient in scientific content to increase their understanding of a certain topic of study. Mathematical knowledge of teachers significantly influences what and how teachers teach, as well as what and how

students learn [3]. The ability of PSTs to assess students' thinking and engage in the optimal learning process may be limited by their insufficient understanding of the CK [4]. However, mastering CK alone is insufficient for efficient learning. Teachers also need to understand how to effectively deliver that knowledge through pedagogy, which is referred to as pedagogical content knowledge (PCK). Unsurprisingly, the PCK conceptual framework has been adopted by scholars of arts education to elucidate the reasons behind the challenges faced by numerous kindergarten teachers when teaching visual arts to young children [5]. According to certain earlier research, teachers, particularly those in elementary schools, do not fully comprehend mathematics [6]. Furthermore, studies have demonstrated a correlation between pedagogical skills and mathematics content knowledge (MCK) [7], [8]. Also, prior research has shown a direct correlation between pedagogical knowledge (PK) of mathematics and MCK [1], [9].

Whereas PCK comprises understanding of how students perceive the subject matter and how to plan and oversee the learning process [10], MCK includes the knowledge that must be acquired and mastered in order to teach mathematics. It is indisputable that learning mathematics, particularly in elementary schools, presents challenges for both teachers and their teaching resources. For example, Waswa and Al-Kassab [11] established that instructors and instructional materials are another factor affecting students' understanding of mathematics in the Kurdistan region, and the few available teachers are ill-trained and ill-equipped to do their job. The proposed research question was: how do PSTs feel about their MCK, PCK, and their readiness to teach mathematics in middle schools?

This study seeks to accomplish two objectives. The first is to look into how secondary PSTs who take part in a mathematics teaching unit view themselves as they interact with and solidify their MCK. The second is to investigate, considering their latest higher education, how these PSTs view and understand their "readiness" to take on such a task. Both objectives will be examined throughout the study project's two phases. The relevance of this study comes from the conviction that the unit mathematics teaching for early adolescents effectively builds students' MCK and PCK, and that further research in this field can support efforts to prepare PSTs in the future. The unit may specifically affect how PSTs of mathematics are properly qualified to teach mathematics in the classroom. This study differentiates itself from existing research by explicitly linking PSTs' self-view to content engagement, suggesting holistic recommendations for teacher training, and focusing on perceived readiness. The major aspects of novelty in this study are the new context (i.e., Morocco) and how this context provides an opportunity to explore PSTs' perceptions through an in-depth qualitative approach regarding specific areas of geometry within a curriculum.

2. LITERATURE REVIEW

2.1. Mathematical content knowledge

MCK is a full, broad, connected, and comprehensive understanding of mathematics [6]. MCK has been characterized by a number of concepts, such as mathematical literacy [12], computational fluency [13], and quantitative literacy [14]. It includes mathematical reasoning and the ability to use mathematical concepts, procedures, facts, and functions to describe, explain, and predict phenomena [15]. Focusing on PSTs' CK is essential to properly educating teachers. Nonetheless, there is disagreement over what MCK is required for successful teaching [16]. It is possible to strengthen the high CK among elementary tutors [6]. Research highlights that preservice teachers often enter teacher education programs with gaps in their mathematical knowledge, which can impact their ability to teach mathematics effectively [17]. To address these issues, educators and researchers emphasize the importance of developing CK and specialized content knowledge (SCK) for teaching. For example, Dogbey [18] developed a professional development program to help teachers in elementary schools to improve their teaching of mathematics using classroom discourse and came up with new methods with whole fraction and number computations. The 21 American elementary school teachers participated in this initiative. The study's findings showed that although participants reported some difficulties implementing the knowledge they gained from the professional development program in their classrooms, they improved their understanding of mathematical content and their instructional strategies. In many states in the United States, before receiving their teaching certification, prospective secondary math teachers must pass the Praxis II: MCK (10061) test [19]. This assessment tests the MCK of PST undergraduates, but not their PCK or comprehension of the mathematical concepts they are going to teach in a secondary school.

Rodrigues *et al.* [20] mentioned the importance of structured frameworks for developing mathematical reasoning processes in prospective teachers. It can be seen from the data that the starting point of the preservice teacher's mathematical skills is very low. Therefore, mathematics teacher training should impose the need for rigorous CK development [21]. The learning process in classrooms, particularly the interactions that take place throughout the learning process, is impacted by the primary school teacher candidates limited MCK. For instance, a prospective teacher may attempt to examine errors in a learning material but fail to recognize the flaws [1]. This will affect how he or she chooses and generates educational

materials for a lesson and offers clarifications in class. The prospective teachers' knowledge also affects how they use students' past knowledge as part of the learning process and how they provide stimulus to the pupils.

2.2. Pedagogical content knowledge

PCK is knowledge required for teachers to comprehend student misconceptions, comprehend the structure and delivery of themes, and affect the capacity to modify sessions to fit all learners [10]. PCK is also a fundamental component for conducting learning activities. In addition to delivering material, the teacher's tasks also include creating educational activities and assisting students who struggle with learning [22]. One widely accepted condition for developing PCK is teachers' CK. CK is the conceptual understanding of school mathematics and the capacity to reason and evaluate different mathematical concepts and situations, and solve mathematics problems in school curricula [23]. Prior studies have noted a positive correlation between teachers' CK and PCK [23], [24].

Mathematical teaching experience is considered as the content-specific knowledge for instruction, which encompasses teachers' PCK, CK, and the capacity to recognize content-related problems during mathematics instruction [23]. Previous research has shown that the quality of mathematics instruction and students' mathematical learning are significantly influenced by the content and PCK of teachers [25]. However, there is conflicting empirical evidence about the degree of variability among the components of content-specific knowledge. Results from previous empirical studies on the dimensionality of content and PK of material have been inconsistent. Because numerous conceptualizations of teachers' knowledge have been examined on various populations, it is challenging to identify the reasons behind the inconsistent data. The content and PCK of elementary school teachers, for example, have been shown to be a single construct in dimensionality studies [24]. In contrast, studies with secondary mathematics teachers have found that teachers' content and PCK are separate constructs. Teachers use PCK as a tool to help students understand, connect with, and find a topic more engaging [26]. Teachers display PCK for a specific subject when they are able to engage students with a range of interests and skill levels by connecting the topic concepts to other topics, employing different topic representations, or changing their teaching style [27]. While the scientific community has not yet agreed on a common conceptualization of PCK [23], [28], [29], it is generally recognized that it includes both PK and CK [27], [28]. The literature review demonstrates that PCK entails planning a well-designed lesson and adjusting it based on students' performance after it is implemented. The PCK is both specific to a particular topic and a target group of students in terms of grade and social context [30]; however, PSTs require orientation toward a deeper understanding of students' ideas, as well as encouraging interactions about student outcomes and potential causes of students' challenges.

The search in a number of scientific databases like Scopus, Web of Science (WoS), ERIC, and Google Scholar revealed the lack of Moroccan studies addressing the assessment of teachers' MCK or PCK. However, it pointed to the existence of some studies addressing these categories of knowledge in North Africa and the Middle East. For example, Sayed [31] discussed the level of mathematical knowledge necessary for teaching mathematics and the attitude towards teaching it among PSTs in Egypt, and Alotaibi and Yousse [32] identified the degree of MCK among secondary school mathematics teachers in Saudi Arabia and its relationship to mathematical pedagogical content knowledge (MPCK). To achieve the research objective, the researcher prepared two instruments: the MCK test and the MPCK scale for secondary mathematics teachers. Given this gap, the present study aims to adapt a survey instrument questionnaire in Moroccan lower secondary schools, helping to identify and strengthen the MCK and PCK of PSTs and providing valuable insights into PSTs' mathematic knowledge, thereby contributing to the enhancement of teacher education programs. Accordingly, the steps of a research method using a thematic analysis of the data are described in the following section.

3. RESEARCH METHOD

3.1. Context

At the regional center for education and training professions, Fez-Meknes, Morocco, the unit mathematics teaching for early adolescents is offered to students who have had a bachelor's degree in mathematics and benefit from training to become middle school teachers of mathematics. Participants can use the unit to pursue a specialization or major in mathematics education. The unit is carried out over 23 weeks with 68 hours of interaction time divided into two semesters with 34 hours in each semester. During interaction hours, PSTs study important curriculum and policy papers, engage with the middle school math subject, learn the best pedagogical strategies for teaching that content, ensure active participation in various training activities (lectures, tutorials, and practical work), and analyze the scientific and official documents relating to mathematics education and group productions. In each semester, students complete three tests related to the unit: a final summative exam (FSE) and two mid-semester tests (MST). Students must demonstrate mastery of the mathematical material presented in the first seven weeks of each semester in order to pass the two-hour MST. The FSE is a 3-hour assessment consisting of direct questions, multiple-

choice questions, and tasks involving the processing and the analysis of teaching situations. The exam covers several areas, such as concepts and approaches in teaching, mathematical reasoning, and the theory of teaching situations. About 60 students are enrolled in this unit each semester.

3.2. Instrument adaptation

To look into how PSTs who take part in the mathematics teaching for early adolescents unit view themselves and to investigate how these PSTs view and understand their readiness to teach mathematics in middle school, an adapted version of the survey of Hine [19], a 7-item, 5-point Likert scale question, and three qualitative questions were used to collect participants' self-perceptions. The researcher employed two qualitative assessments to gather information from research participants. Before starting a 23-week tertiary course centered on mathematical content, participants were required to answer four research questions. Then in stage 2, the participants will be given exactly the same study questions, which will take place right after this unit is finished. The primary research methodology used in this interpretative study was the qualitative method. Some of the elements were adapted in response to the input received:

- The qualitative questions 2, 3, and 4 were restricted to teaching lower secondary schools. They are the same of those of Hine [19].
- The items of question 1 were restricted to teaching lower secondary schools and were adapted according to the Moroccan educational system. This adaptation is illustrated in section 4.1 (seven topics).

3.3. Sample

The stages and criteria for selecting the study sample can be summarized as:

- At the regional center for education and training, inviting PSTs engaged in the early adolescents' mathematics teaching unit, and learning to teach mathematics in lower secondary schools, to participate in this study (60 participants). As this center is the unique center in the region that trains this category of teachers.
- Request to the aforementioned category of PSTs to express their interest in participating in completing the questionnaire. Thirty PSTs showed their interest and accepted to participate in this study.
- The response of any participant that was found to be incomplete was removed. Five responses were removed.

Following these stages, a self-selected sample (25 participants) for stage 1 of the project was constituted. Of the 25 PSTs, 15 PSTs were completing a Bachelor of Mathematics and Computer Sciences (BMCS) degree, and 10 a Bachelor of Mathematics and Physics (BMP) degree. More details are available in Table 1.

Table 1. Project participants (Stage 1)

Gender	BMCS	BMP	Total
Male	9	5	14
Female	6	5	11
Total	15	10	25

3.4. Data analysis

The 25-pre-unit questionnaires' data were examined for common themes. A thematic analysis of the data was performed following the framework and recommendations provided by Miles and Huberman [33]. Based on differences and similarities between social phenomena, this framework helped the researcher find connections between them. The three primary components of the technique are data reduction, data display, and conclusion drawing and verification. Coding, memoing, and proposition development are the three primary tasks involved in these components. Codes are "tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study," according to Sayed [31]. These codes were chosen based on their meaning and attached to the information obtained from the questionnaires. The coded data were then combined by the researcher using memoing to create a distinguishable cluster based on a single overarching idea. The researcher's continuous ideas during the coding procedures were likewise recorded by the memoing technique. Finally, the requirement to "formalize and systematize the researcher's thinking into a coherent set of explanations" increases as a study goes on Sayed [31]. During phase 1 of this study, we developed hypotheses on related sets of participant statements, we considered the results, and we generated first conclusions.

The validity of this study in the context of MCK is fundamentally acceptable because it used thick descriptions of the context and it is based on the principle of diversifying the way questions are asked or using multiple data sources or methods within the same instrument to confirm or cross-validate findings. The statistical conclusion is enriched and made meaningful by the specific, contextual reasons derived from

the direct questions. This holistic understanding gives readers more confidence in the study's conclusions. The study's reliability is made possible by the fact that it is carried out among PSTs obtaining bachelor's or master's degrees from several Moroccan universities. It remains to be seen if the themes discovered are likely applicable and transferable to other PSTs cohorts in similar scenarios.

4. RESULTS

4.1. Readiness to teach mathematics

Every participant (25 out of 25) expressed how prepared they were to teach lower secondary student's mathematical content. Regarding the seven available content topics (numbers and numerical calculations, algebra and literal calculations, proportionality and functions, geometry, measurements, graphic and statistical activities, and logical reasoning and problem solving), participants rated themselves on a Likert scale from 1 to 5, where 5 signifies that they feel entirely ready and 1 indicates that they are least ready. Overall, participants declared that they felt least ready to teach geometry (mean=3, SD=0.86) and most ready to teach numbers and numerical calculation (mean=4.36, SD=0.75). Although not very much, the mean score for each issue showed that participants felt qualified to teach mathematics in middle school (3<mean<4.36). Table 2 displays these data.

Table 2. Self-perceptions on teaching content

Topic	1	2	3	4	5	Total	Mean	SD
Numbers and numerical calculation	0	1	1	11	12	25	4.36	0.75
Algebra and literal calculations	0	1	1	16	7	25	4.16	0.70
Proportionality and functions	1	3	3	14	4	25	3.68	1.02
Geometry	1	7	10	5	2	25	3	0.86
Measurements	2	2	4	12	5	25	3.6	1.10
Graphic and statistical activities	1	4	5	9	6	25	3.6	1.15
Logical reasoning and problem solving	1	4	6	10	4	25	3.48	1.08

4.2. Readiness to teach students

Every participant (25 out of 25) gave a range of responses about how ready they felt to teach lower secondary students. The researcher distinguished between three categories of qualitative responses: uncertain, confident, and unconfident. Out of 25 participants, 12 expressed that they felt confident to teach mathematical material. Some participant replies consisted of:

> "*Concerning the content, I can say that I'm ready to teach this subject*."
> "*I think I am qualified to teach mathematics with a high retention rate because of my strong academic background and breadth of mathematical knowledge*."
> "*I am qualified to teach mathematics to students of early secondary school. I have sufficient subject knowledge and pedagogical skills because I have experience in teaching mathematics in private schools. Also, I have experience in technology and teaching, so I can use these experiences to motivate students to learn*."

Of the 25 PSTs, 10 said they were unsure about teaching; for most of these replies, participants said they needed different amounts of additional MCK and PCK. For example, some participants mentioned:

> "*I think that the various skills I have acquired during the years of my schooling and teaching experience can be helpful when it comes to teaching mathematics. However, it's still not enough, and in order to expand my knowledge and apply it in the classroom, I must get an education in teaching*."
> "*For me, I am quite competent concerning mathematic CK in early secondary school, even though there are some issues and gaps, but the serious problem is how to convey or share information with students slightly*."

Only three out of 25 participants said that they were unconfident in their ability to teach mathematics. One of them stated, "*actually, with the mathematical knowledge and skills that I have, I am completely not ready to teach mathematics, but I hope to improve my pedagogical and content knowledge*." These findings allow us to propose some sub-themes, such as the role of experience in the confidence to teach mathematics and growth mindset. For the first sub-theme, the most confident respondents specifically mentioned "experience in teaching in private schools" or "technology experience", which suggests that self-

confidence is significantly influenced by prior classroom experience. For the second one, we see that even among the "unconfident" and "uncertain" groups, there is a stated desire to expand knowledge and get an education in teaching; they are pointing out a particular need for additional training and technology integration, not rejecting the profession. Additionally, one participant connected his self-confidence to his capacity to motivate students through technology, indicating that contemporary PSTs may view digital literacy as a fundamental aspect of their identity as educators.

4.3. Mathematical content knowledge support needed

With a striking 96% of PSTs (24 of 25) stating that they needed more MCK to effectively teach lower secondary students, a clear area for attention emerges within Moroccan teacher training. Furthermore, the participants selected specific elements of the Moroccan curriculum that they believed required more MCK support. In particular, the overwhelming majority of PSTs (15 of 24) stated they needed assistance with the geometry component. Various participants' comments about geometry support included:

> "*I think that geometry is the area where I most need more training because during my years of high school, I concentrated on algebra and analysis*."
> "*I have no issue teaching math to junior high school students, but I think I need more training to improve my geometry skills*."
> "*Even though I am ready, I encounter a number of difficulties in the discipline of geometry*."

A significantly lower percentage of PSTs stated that they required further MCK from the Moroccan curriculum components of statistics (1 of 24), analysis (3 of 24), logical reasoning and problem solving (2 of 24), and all fields of mathematics knowledge (3 of 24). Among the three out of 25 who reported feeling "unconfident", one said "*not yet; however, I have no doubt that I will discover some fields in which I need support*."

4.4. The unit's contribution to understanding mathematical content

According to the predictions of all participants (25 out of 25), mastering the unit would help them prepare to teach mathematics. Specifically, the overwhelming majority of participants (24 out of 25) agreed that this module would help them strengthen their PCK or MCK or both of them. A sample of PSTs' statements is:

> "*This course, in my opinion, will provide me with the proper methods for teaching mathematics and handling the various issues that may arise in the classroom*." (Student 1)
> "*This unit will assist me in expanding and comprehending my mathematical knowledge, particularly in relation to some of my deficiencies in geometry*." (Student 6)
> "*With the support of the education and training center's educators, I think this training will help in understanding MCK. This training includes effective lesson planning and the management of a unique concept. Furthermore, middle school training classes will allow us to switch from a theoretical to a practical approach and assess our level of assimilation of the courses*." (Student 21)

Along with these comments, a few participants (2 out of 25) emphasized that this unit will offer them the confidence they need to properly teach mathematics. As one member pointed out:

> "*I believe that this unit will help shape the teacher's personality in the classroom, enhance his teaching skills and techniques, and enrich his mathematical knowledge*."

According to two out of 25 participants, the lesson might be useful for revising mathematical material. According to one participant:

> "*This lesson will refresh my previously acquired middle school understanding while also imparting new content knowledge, such as fundamental terms and teaching techniques exclusive to middle school mathematics*."

5. DISCUSSION

Examining how middle school PSTs participating in a mathematics education course saw themselves as they implemented and strengthened their mathematical knowledge was the intent of this study. The researcher also looked into the PSTs' perceptions and understandings of their "readiness" to teach

mathematics. The data reveals a distinct dichotomy in the readiness of PSTs. While there is a foundational belief in their general readiness to teach (indicated by a universal positive response to readiness), there is a significant gap between their MCK with high self-rating in numbers and numerical calculation and algebra versus self-rating deficit in geometry which is strongly corroborated by the qualitative feedback. The root cause of this deficit appears to be systemic. It seems that participants' prior academic training likely concentrated on algebra and analysis, leaving them under-equipped to teach geometric concepts. This indicates that the PSTs are not struggling with mathematics capability, but rather with a specific curricular blind spot. Furthermore, a "confidence gap" exists where perceived subject mastery does not automatically translate to pedagogical confidence. This confidence appears correlated with experience. Participants who had taught in private schools reported higher confidence. This suggests that readiness is viewed by PSTs as a practical skill set acquired through doing. The participants view the training unit as a crucial bridge to cross this gap, specifically to transition from theoretical knowledge to practical classroom application. The collected data was categorized into two conceptual concerns. Among these concerns are the need to improve MCK and PCK and meaningful professional learning. Both of these concerns are now taken into account in light of the research on the development of mathematics PSTs.

5.1. Meaningful professional learning

Each of the 25 research participants emphasized the significance of mathematics teaching for early adolescent unit for their professional growth as PSTs of mathematics and so enhancing their current level of readiness to teach students. Furthermore, a lot of PSTs were able to express how helpful they thought the unit would be for their professional lives. The majority of participants, for example, hope that this unit would help them learn all the techniques and methods of teaching mathematics and make the mathematical concepts of this level clear, understandable, and accessible to the early secondary school class, and therefore improve PSTs' PCK and MCK. Others reported that the unit will give them confidence in their ability to teach and consolidate mathematics, whereas others described it as "a good content refresher". The findings align with previous research that highlights the importance of mathematics units for PSTs [19], [34]. Ten participants of 25 said they were unconfident about teaching lower secondary mathematics, and three PSTs reported feeling uncertain. According to this claim and the fact that most respondents (24 out of 25) said they felt they needed more MCK and PCK, this course appears to be very beneficial for preparing future teachers in mathematics. The participants indicated that the unit would improve their MCK, PCK, or both, even that participant who had a confidence rating in their MCK. These self-reported responses from participants about the unit's worth are in line with those of other academics [19], [35]. The data reflects a highly optimistic and growth-oriented cohort. Despite 96% of participants stating they need more CK, this is not framed as a failure but as a roadmap for the training unit.

5.2. The need to improve MCK and PCK

In light of the study participants' affirmations of the need to complete this unit, gathered testimony often emphasized PSTs' self-reported need to consolidate their MCK and PCK. A total 13 out of 25 participants, or more than half, said they were unconfident or uncertain in teaching mathematics. According to the majority of participants, they needed help understanding how to teach mathematics to pupils after feeling least confident in their MCK and PCK. These claims support the idea that PCK is crucial for mathematics teachers in teaching and learning due to the fact that mathematics is an abstract and interrelated subject requiring adequate knowledge of the content and instructional practices [22] and the belief that mathematics teachers need training programs that suit their specialized teaching needs in order to keep pace with developments and activate experiences among them [36]. More than 50% of those who recognized that they needed additional support to improve their MCK (15 out of 24) indicated that geometry was the Moroccan curriculum strand in which they needed help the most, followed by analysis and logical reasoning (5 out of 24). This aligns with many studies that stressed building training programs designed to develop and support the growth of knowledge of mathematics teachers, as some mathematics teachers have limited knowledge of mathematics education, yet they teach it [37]–[39]. The research participants focused especially on the necessity of combining the MCK and PCK they need to teach students with confidence and competence, even though current literature indicates that mathematics teachers should enhance their PK, CK, PCK, and MCK overall. This focus is consistent with the argument made by a number of academics that teachers must have a solid understanding of MCK in order to support students' learning [19], [34], [35].

6. CONCLUSION

This study examined the self-perceptions of PSTs in middle schools participating in a mathematics teaching course as they prepared to interact with and solidify their mathematical knowledge. The comprehension of their "readiness" to take on a task of this kind was also examined. The research

participants' testimonies confirm the hypothesis that participants need more assistance in improving their MCK and PCK, which is already supported by a body of literature. Simultaneously, the data obtained during Phase 1 shows how much PSTs think completing a unit on mathematics content will help them in their future careers. Acquiring MCK, PCK, or any combination of these knowledges was highly valued. Specifically, all participants stated that they thought this unit would be helpful in strengthening and consolidating their MCK and PCK. The study suggests a major issue with self-efficacy and professional readiness and points out the need for earlier and more intense practical experience combined with strong mentorship. PSTs have perceived significant gaps in their MCK related to geometry and PCK related to teaching in general. Therefore, it would be beneficial for the teaching unit to include specific content area MCK and generalized teaching methods in the course structure. Trainees need experienced professionals to guide them, offer constructive feedback, and share professional insights.

Although this study is considered an effective and essential tool for reducing the gap in mathematics education fields in the Arab world, the study has certain limitations. First, the study sample was drawn from a single region of Morocco, with just 50% of the sample self-selected to participate; therefore, the results may only be applicable to a specific group of people. The results would be far more thorough and generalizable if the study was expanded to include a larger and more varied sample from other Moroccan regions. Second, this questionnaire should be used in conjunction with other measurements, such as interviews or classroom observations, in future research to lessen any potential biases. Additionally, only PSTs in Moroccan lower secondary schools were included in this study. In order to ascertain whether the findings of this study apply to other situations, it is recommended that differences in confirmation of the finding between in-service teachers and PSTs in lower secondary schools be studied.

Based on the findings of this study, a number of implications for either policy or teacher training practice can be proposed. For the first one, policy should shift from treating MCK and PCK as separate entities. Instead, it should mandate integrated units where PSTs learn advanced mathematics concepts through the lens of middle-school pedagogy; also, given that over 60% of those needing help pointed specifically to geometry, policy should consider "strand-specific" micro-credentials or intensive modules within teacher certification to ensure mastery in historically difficult areas. For the second one, training programs should allocate more instructional hours to geometry, analysis, and logical reasoning, as these were identified as the primary sources of uncertainty. Also, programs should implement frequent micro-teaching sessions where PSTs practice explaining abstract concepts to peers before entering a real classroom to address the uncertain group (who know the math but fear the conveying). Additionally, the training should prepare individuals for the emotional demands of the job (e.g., stress, burnout, managing difficult situations, or dealing with professional setbacks). The course could involve emotional intelligence training and teaching techniques for stress management and work-life balance.

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AUTHOR CONTRIBUTIONS

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
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O : Writing - **O**riginal Draft
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P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY

Data are available from the corresponding author, [JA], upon reasonable request.

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