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Exploring mathematics teacher education programs in Vietnam: Perspectives from the requirements of the Fourth Industrial Revolution and the TPACK framework

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ABSTRACT

The Fourth Industrial Revolution (4IR) has been bringing substantial changes to everyday conduct, particularly in education activities. Past researchers have highlighted multiple aspects that must adapt to satisfy 4IR's developmental requirements, including changes in the teaching of Mathematics in high schools to provide high-quality human resources for society in the future. To do so, countries need to have strategies to train Mathematics teachers, in which special attention should be paid to renewing the training programs in the direction of strengthening courses in information technology and STEM education. To assess the current state of mathematics teacher training programs in Vietnam in this context, this study aims to analyze the training programs of seven key pedagogical universities. The research method involves analysis of documents and synthesis of the training program's content using the Technological Pedagogical Content Knowledge (TPACK) model.Our results show that the structure of mathematics teacher training programs at core pedagogical universities in Vietnam is currently unsuitable for the TPACK framework. Most programs place excessive emphasis on equipping students with extensive knowledge of Mathematics, which may not be frequently utilized in their profession. In addition, students have very limited exposure to and understanding of crucial topics such as data analytics, digital technology, and STEM education, which are critical to human knowledge in the 21st century. The research results of this article provide evidence for Vietnam, as well as other countries, to evaluate and adjust training programs for mathematics teachers to nurture future mathematics educators who will better meet the requirements of modern education.

Contribution/Originality: This paper is the first to select and analyze the training programs for Mathematics teachers at the seven largest pedagogical universities in Vietnam based on the TPACK framework. The research results provide readers with basic insights into the training of Mathematics teachers in Vietnam.

1. INTRODUCTION

The Fourth Industrial Revolution (4IR) encompasses multiple disruptive technologies such as virtual reality (VR), the Internet of Things (IoT), robotics, and artificial intelligence (AI). They are reshaping every aspect of developing and developed economies and industries across the globe. They are also changing the way we live and work and are having an increasing impact on our lives (Kayembe & Nel, 2019; Ng & Tsang, 2023; Quyet, 2020; Schwab, 2017). Besides redefining the norms of industries and economies, these advancements also require a paradigm shift in education (Layco, 2022; Ng & Tsang, 2023; Quyet, 2020; Schwab, 2017). The urgency of this change was highlighted by Schwab (2017) stating that *the development of educational models where humans can work* *alongside increasingly intelligent, connected, and capable machines is necessary.* The 4IR era has brought rapid changes to education systems across the globe (Mifsud & Orucu, 2025) because this era requires students – who will lead and drive change to develop new skills. As a result, traditional educational models are facing unprecedented challenges, and outdated teaching methods are now insufficient to help students navigate the complexities of the modern world (Ng & Tsang, 2023). Therefore, it is vital to create new educational models in which the teaching process involves constant interactions among four key elements: teachers, students, knowledge, and technologies. Teachers must adapt because they are the backbone of any education system, directly affecting the quality of teaching and learning, and they are imperative in equipping future generations with the skills and knowledge needed to adapt and develop in this rapidly changing context (Ayanwale, 2023; Boadu & Bonyah, 2024; Grenčíková, Kordoš, & Navickas, 2021; Madalinska-Michalak, 2024; Naidoo & Reddy, 2023).

Mathematics has always played a fundamental role in technological and scientific advancements, serving as an essential tool in optimization, data analysis, and problem-solving in all scientific fields (Layco, 2022). As society increasingly relies on data-driven decision-making, problem-solving, and interdisciplinary collaboration, the importance of mathematics as a foundational subject is undisputed (Ng & Tsang, 2023). Given such a pivotal role, an important area that needs immediate attention is the training of mathematics teachers. Since teachers are responsible for disseminating knowledge to students, they need to have a deep level of expertise and the flexibility to adapt their teaching methods to 4IR's complex requirements (Naidoo & Singh-Pillay, 2020). To overcome these challenges, mathematics teachers must receive training on appropriate and essential skills, with an emphasis on improving the flexibility and application of technologies in teaching through professional development programs (Abdelrazeq, Janssen, Tummel, Richert, & Jeschke, 2016) especially teacher training programs. Innovation in these programs is therefore crucial to match the trend of technology integration into education, particularly in Mathematics education (Ayanwale, 2023). Over the years, there have been many studies on the incorporation of technologies into training programs, of which the TPACK framework is highly regarded among institutions as a creative and effective way to build and develop teacher training programs.

Vietnamese students often perform well in internationally standardized exams such as the Program for International Student Assessment and the International Mathematics Olympiad (Asadullah, Perera, & Xiao, 2020). However, the country's economic development is relatively slow, with low to medium income per capita and limited technological readiness. Therefore, the country faces major development obstacles, including high energy demand, depletion of natural resources, and environmental pollution (Asadullah et al., 2020; Quyet, 2020). Therefore, without innovation in education, especially in training Mathematics teachers, Vietnam may bear all the negative impacts of the Fourth Industrial Revolution (4IR), particularly on its human resources. Current training programs for Mathematics teachers tend to prioritize in-depth mathematical knowledge but lack focus on technology skills, STEM integration, and interdisciplinary approaches. Such imbalance can cause future Mathematics teachers to be incompetent in guiding students in a rapidly changing educational environment. To address these issues, this study examines the current state of Vietnamese training programs for Mathematics teachers based on the requirements of 4IR and the TPACK framework, analyzes existing limitations, and seeks opportunities for innovation. The following core questions guide the research and suggestions:

1. What challenges do mathematics teachers face in the context of the Fourth Industrial Revolution (4IR)? What specific competencies do they need to meet the requirements of 4IR?
2. How does the TPACK framework support the improvement of technological and pedagogical skills for Mathematics teachers?
3. What is the current situation regarding Vietnamese training programs for Mathematics teachers? What are the limitations that hinder teachers from meeting the requirements of the Fourth Industrial Revolution (4IR)? What changes are necessary for the training programs to align with 4IR requirements?

2. METHODS

To deliver this study, the authors analyzed and synthesized relevant literature to highlight key characteristics of the Fourth Industrial Revolution (4IR), its significant impact on Mathematics education, and the challenges it poses to teachers. We then consolidated the TPACK framework resources to demonstrate their relevance in designing training programs for Mathematics teachers in the context of 4IR. This was followed by a selection and comparison of training programs for Mathematics teachers from seven highly ranked pedagogical universities in Vietnam. The goal is to understand these programs' suitability with the TPACK framework and 4IR's requirements.

3. THEORETICAL FRAMEWORK

3.1. 4IR's Key Characteristics and Impact on Education

Schwab (2017) stated that 4IR is not just about complex connections among intelligent systems and machines that lead to breakthroughs in new and essential sectors like renewable energy, quantum computing, genetic sequencing, or nanotechnology. The revolution also comprises the interaction and convergence of these technologies in key infrastructure and scientific fields. Such innovations make 4IR fundamentally different from previous revolutions and explain why it is often described as the result of technological integration with resonant impact on "explosive" technologies. The power of 4IR lies in the strong convergence of emerging technological breakthroughs, including but not limited to AI, IoT, robotics, 3D printing, autonomous vehicles, biotechnology, advanced energy storage, materials science, and quantum computing (Naidoo & Singh-Pillay, 2020; Oke & Fernandes, 2020). The traditional composition of the labor market is therefore dismantled, as many jobs become obsolete or automated, while others requiring extensive mastery of new technologies are sought after with high remuneration (Ayanwale, 2023; Schwab, 2017).

Compared to previous revolutions, 4IR has so far yielded fewer jobs in new industries. However, it is widely believed that a proper combination of digital, physical, and biological technologies which are driving forces behind today's constant evolution – will help improve the productivity and thinking capacity of workers. This means that new participants in the workforce must learn to acquire educational models that enable collaboration with increasingly intelligent and highly connected machines (Schwab, 2017). The impacts of the Fourth Industrial Revolution (4IR) vary depending on industries, including both new opportunities and challenges for education (Kayembe & Nel, 2019). 4IR's diversity and practicality can transform education, particularly mathematics education, into systems capable of solving new challenges. Each country's educational institutions should adhere to relevant strategies that leverage new 4IR technologies, such as big data, blockchain technology, and AI, rather than relying on traditional processes.

According to Naidoo and Singh-Pillay (2020) graduates will no longer follow a simple linear path or be tied to a single role throughout their working lives. They are more receptive to change and can hop between jobs to find the most satisfying work-life balance. Therefore, what they yearn for most through learning is the ability to learn and relearn continuously, which helps them adapt to major changes in technology, environment, economy, and society. Consequently, professional development for their teachers is vital in fostering critical skills that students need to adapt to the Fourth Industrial Revolution in the 21st century, especially as the necessary skills for working, living, and maintaining successful careers have become increasingly complex.

In the future, the roles of teachers can be summarized as ensuring lifelong learning for students and providing them with practical experiences regarding market fluctuations and socio-economic changes. Therefore, 4IR will create the concept of "Teacher 4.0," which is defined by Abdelrazeq et al. (2016) as a teacher who can master new technologies and effectively apply them in teaching students, this study asserts that a "Teacher 4.0" must adapt to the new requirements of his/her job and take on appropriately adapted teaching roles. Pedagogical universities, accordingly, need to prepare and assist "Teachers 4.0" in a complex teaching context by curating new frameworks and curricula to respond to labor market volatility.

In the view of Ng and Tsang (2023) rapid technological developments of the 4IR are accompanied by equally rapid advances in education, particularly in technology-assisted teaching methods. Over the past two decades, the integration of digital technology into schools has introduced new approaches to mathematics teaching and representation.

Teachers' professional development can occur in both formal and informal contexts. Formal contexts include teaching study groups, professional development programs, and structured mentorship initiatives, while informal contexts encompass collaborative planning, peer-to-peer teaching, and mentorship among peers (Timperley, 2008). Regardless of the form, evidence suggests that teachers can only benefit from any training if it is customized to their specific area of expertise (Darling-Hammond, 2017).

3.2. Some Challenges Math Teachers Face when Teaching in the Context of 4IR

3.2.1. The Decline in the Professional Position of Teachers

In a digital society, mathematics is not only used in daily life functions and transactions, but it also serves as the foundation for Industry 4.0. If, in everyday life, we use quantities like area, length, mass, and time, then in the context of the Fourth Industrial Revolution, students also need to familiarize themselves with concepts like humidity, profit, air pressure, or population growth (Gravemeijer, Stephan, Julie, Lin, & Ohtani, 2017). They also need to master how to apply statistics to big data analysis and use knowledge of spatial geometry to understand three-dimensional images and printing technology. Thus, mathematics is the essence of the digital era, and students' mathematical abilities need to be developed through Education 4.0 (Gravemeijer et al., 2017). Oke and Fernandes (2020) claim that 4IR can change teaching and learning opportunities by adapting the way students engage in the learning process. Students can easily access learning materials and choose the right tools and methods to acquire knowledge (Layco, 2022; Oke & Fernandes, 2020). Moreover, they can easily find virtual or artificial intelligence teachers who are ready to support their learning (Abdelrazeq et al., 2016; Ayanwale, Ndlovu, & Oladele, 2022). Therefore, to maintain their role in the context of 4IR, Mathematics teachers need to shift from purely transferring knowledge to facilitating the learning process and helping with the orientation and promotion of the development of students' thinking. At the same time, teachers must adapt to new requirements, adjust their teaching styles, and conduct their classrooms accordingly. This requires a solid and comprehensive mathematical foundation to adopt advanced technologies in teaching, problem-solving skills, creative thinking, and effective communication. At the same time, "Teacher 4.0" must be dynamic, persistent, and flexible while possessing a global awareness of the era of 4IR (Ayanwale et al., 2022).

3.2.2. The Lack of Knowledge and Technological Skills among Teachers

4IR, with digital technology and open-source content, presents a new opportunity to revolutionize teaching methods through acquiring, re-acquiring, and eliminating outdated knowledge. Technologies provide teachers with new opportunities to tailor teaching methods to their students' learning abilities (Ayanwale et al., 2022). With Mathematics education, Ng and Tsang (2023) believe that 4IR and its recent technological advancements *will open up* new approaches to *learning the subject. They also argue that the future of Mathematics education will depend on teachers' ability to implement appropriate pedagogical methods to work with new technologies.* Within 4IR, students and their schools must adapt to the integration of advanced technologies installed on their tools and platforms for teaching and learning (Naidoo & Reddy, 2023). Therefore, teachers must gather knowledge about digital technologies and learn how to apply them to their teaching process. This should not be limited to existing technologies but also include new tools to keep them updated and improve their teaching effectiveness (Ab Jalil, Rajakumar, &

Zaremohzzabieh, 2022). However, many teachers who are currently practicing still require support in integrating emerging technology platforms into their teaching methods (Hu & Garimella, 2014).

Schwab (2017) points out that many teachers possess inadequate knowledge and skills to master new technologies. These are mostly senior teachers who are not fully aware of or intrigued by the changes that these new technologies may bring. A combination of these factors has resulted in a noticeable gap between the theoretical framework and practical implementation of technologies (Hameed & Hashim, 2022). This means that if teachers cannot handle highly innovative technologies, they often struggle to assist students in using them in learning mathematics and applying subject knowledge as well as knowledge about technologies in daily life.

3.2.3. The Obsolescence of the Mathematics Curriculum

Functioning curricula are central in teaching any subject, including Mathematics (Budak, 2015). They serve as plans to guide the teaching and learning process and tools to help both parties achieve educational goals. A study by Atlantic Evaluation and Research Consultants (2008) on the Canadian mathematics program, it was concluded that teachers believe the country's mathematics program is overloaded. This makes it impossible for teachers at most levels to fully understand and communicate in detail all the goals set out to ensure that students acquire knowledge effectively. A study by Rahmawati, Muttaqin, Fathurrohman, and Ihsanudin (2021) on Indonesia's Mathematics program also came to similar conclusions. Traditional Mathematics curricula, which are often based on machine memorization and static problem-solving techniques, are becoming increasingly inadequate for developing the skills needed in a connected and ever-changing world. To address this gap, a groundbreaking Mathematics curriculum has been developed to equip students in this country with computational, critical thinking, and problem-solving skills—the core elements of success in the 21st century (Ayanwale, 2023).

In his research on Türkiye's Mathematics program, Demir (2024) found that Mathematics programs in European nations and the United States of America focus more on developing students' capacities for mathematical modeling, reasoning, communication, problem-solving, and diverse performance skills, thereby helping students use advanced digital technology and improve critical thinking. However, 4IR means updates to the Mathematics program in the future may include social media and AI platforms to help students improve their problem-solving skills. The improved curricula need to reflect lifelong learning pathways, digital competencies, and math skills that are relevant to the 21st-century curriculum (Naidoo & Reddy, 2023). The Mathematics curricula should reflect the sustainability of technology and focus on promoting technologies that have a direct impact on Mathematics education.

3.2.4. Technology Abuse by Students

Despite many benefits, new technologies also generate negative consequences, especially if they are misused during the learning process for recreational activities (Hameed & Hashim, 2022). Other researchers also suggest that students' increasing reliance on technology can make them more introverted and reduce their social awareness. Due to such dependency, students no longer actively think about ways to solve their problems. Instead, they do most of their research for information online. Having access to too much information may result in interaction with misinformation, which can easily hinder students' learning process (Mashrah, 2017; Mdhlalose, 2023). Several scholars have argued that the overuse of technology, especially artificial intelligence (AI) in education, could undermine students' engagement with theoretical and conceptual knowledge (Mohamed, Hidayat, binti Suhaizi, bin Mahmud, & binti Baharuddin, 2022). Such arguments are further solidified by Avelino and Ismail (2021) arguing that technologies can result in greater abuse once students distribute false information among themselves and to social media, affecting the learning process of others. In this context, teachers must learn how to master technologies to control students' access to their devices, not only when they do not assist learning but also during recording, presenting lectures, or when guest teachers are attending classes.

3.3. TPACK Framework and Application in Teacher Training Programs in the World

In an article titled "Knowledgeable People: Knowledge Development in Teaching" (Shulman, 1986) performs a comprehensive analysis of different aspects of the teaching profession to argue that it is necessary to establish a clear theoretical framework illustrating knowledge blocks that teachers must present in the teaching process. The main questions posed include: What are the scopes and categories of content knowledge that teachers are aware of? What is the relationship between pedagogical knowledge and content knowledge? In what forms are the scopes and categories of knowledge expressed in a teacher's mind? What are the ways for teachers to enhance the acquisition and development of that knowledge? In this study, three types of knowledge are defined: (a) Content knowledge - the amount and method of organizing knowledge of a subject that a teacher already possesses; (b) Pedagogical knowledge - a subject's knowledge and professional understanding in teaching that subject; and (c) Program knowledge - the entirety of a program designed to teach specific subjects and topics at a certain level (Shulman, 1986). It is also necessary to consider the relationship between pedagogical and content knowledge through the concept of Pedagogical Content Knowledge (PCK) because it combines both knowledge blocks to help new teachers understand how to organize, adapt, and express specific aspects of the subject for effective teaching. Mishra and Koehler (2006) argue that these knowledge blocks can be combined into a graph model with a noticeable intersection between content knowledge (C) and pedagogical knowledge (P), forming pedagogical content knowledge (PCK). However, a major shortcoming is that there was no discussion of technological knowledge and its relationship to the other two knowledge blocks. To overcome this limitation, the PCK model was updated into the TPACK model because learning with technologies offers learners an important foundation for the future. Therefore, students need to understand and differentiate between technology and technological competence to interact in society through different communication modes (Naidoo & Singh-Pillay, 2020). However, it is also necessary to acknowledge that multiple challenges exist with the use of technology-based pedagogy. Therefore, when using technologies in teaching, teachers must retain proficiency in using them within a relevant educational context. Understanding how and when to use technologies to support content teaching is known as technology-content pedagogical knowledge (TPACK). The foundation of this model is that teaching is multidimensional and requires intersecting knowledge, as illustrated in Figure 1 (Mishra & Koehler, 2006; Naidoo & Singh-Pillay, 2020).

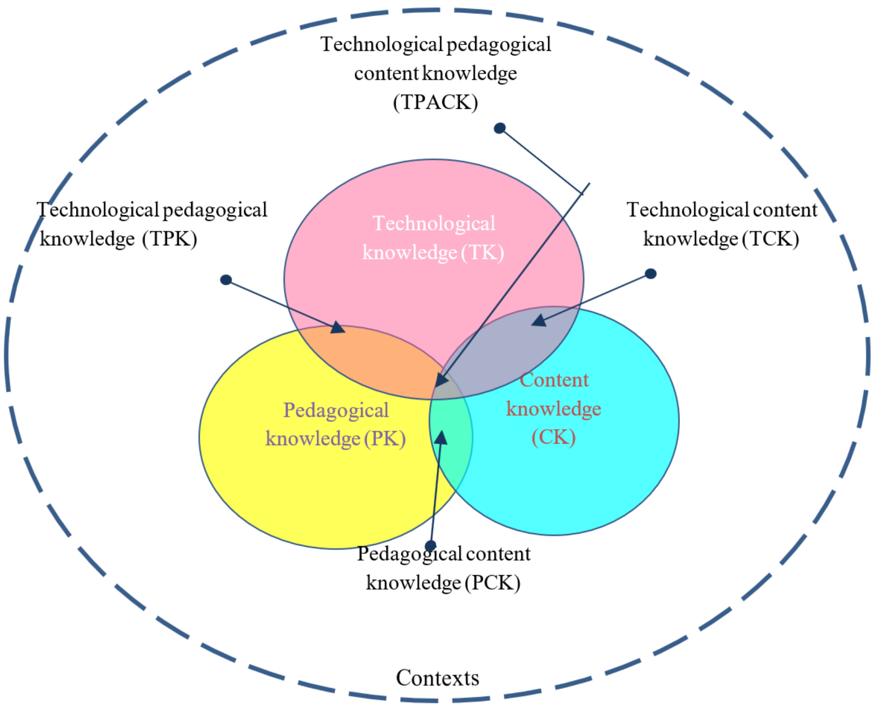

Figure 1. The TPACK framework.

Source: Koehler, Mishra, Akcaoglu, and Rosenberg (2013).

Naidoo and Singh-Pillay (2020) stated that concepts in the TPACK framework include five knowledge components: Content Knowledge (CK): Knowledge of mathematical concepts; Pedagogical Knowledge (PK): Knowledge of teaching methods for mathematical concepts; Technology Knowledge (TK): Knowledge of technology-related issues, including object projectors, laptops, data projectors, and smartphones; Pedagogical Content Knowledge (PCK): Knowledge of pedagogical methods in teaching mathematical concepts; Technological Content Knowledge (TCK): Knowledge of teaching mathematical concepts effectively using specialized technological tools.

The TPACK framework integrates all key knowledge blocks and, therefore, is applied to understand what teachers need to develop their expertise. Furthermore, many researchers recognize the diverse applicability and potential of the TPACK framework and use it as a theoretical framework to improve teachers' understanding of how to use it effectively to support their students' learning process (Tanak, 2020). Given that possessing a solid knowledge and experience in digital technology does not automatically guarantee their successful integration into teaching practice, it is crucial that technology be employed within a meaningful and pedagogically relevant context (Althubyani, 2024). In addition, the TPACK framework serves as the theoretical foundation to help administrators design training and retraining programs to meet the requirements of mathematics teaching in this century (Phan, Van Tran, Truong, Le, & Phan, 2024).

4. RESULTS

4.1. Mathematics Teacher Education in Vietnam

In Vietnam, all pedagogical universities are public institutions (Pham & Nguyen, 2020). These include the seven core pedagogical universities, all established in the 20th century. These universities have autonomy in developing and managing training programs for Mathematics teachers. Concurrently, the Ministry of Education and Training only issues documents regulating compulsory knowledge blocks in teacher training programs. To answer the third research question of this paper, we selected and analyzed the training programs for Mathematics teachers from these seven pedagogical universities at varying levels. According to regulations mandated by the Ministry of Education and Training on ensuring the quality of teachers, the training programs must provide students with a minimum of 120 credit points. The research results show that these training programs range between 126 and 136 credit points (Ministry of Education and Training, 2021). Figure 2 provides statistics on the total number of credit points for these programs.

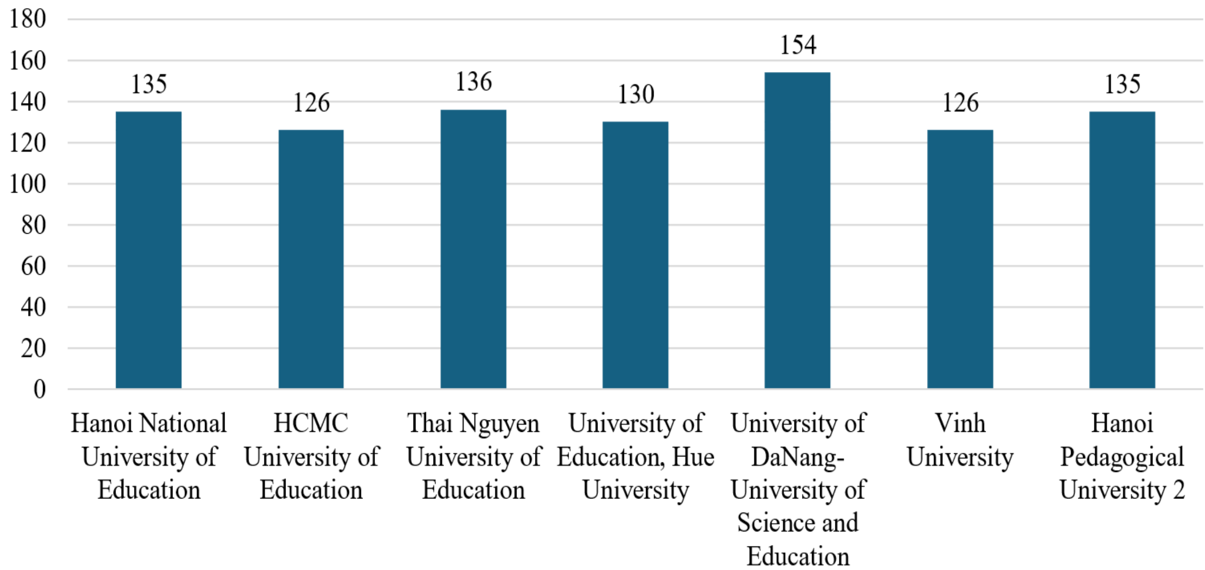

Figure 2. The number of credits students must accumulate in the mathematics teacher training programs of seven pedagogical universities.

To examine the suitability of these training programs for Mathematics teachers within the TPACK framework, we conducted a deeper analysis of these programs. We found that they are divided into four knowledge blocks: general, pedagogical, Mathematics, and vocational knowledge. Thus, the Mathematics teachers' training program of these universities is significantly different from the TPACK framework due to the Vietnamese government's requirement that all pedagogical graduates possess a certain understanding of philosophy, Marxism-Leninism, the ideology of the Communist Party of Vietnam, and foreign languages (mainly English) for communication and comprehensive reading of documents. Information on the number of credit points for each knowledge block in the training programs for Mathematics teachers of seven key pedagogical universities is shown in Figure 3.

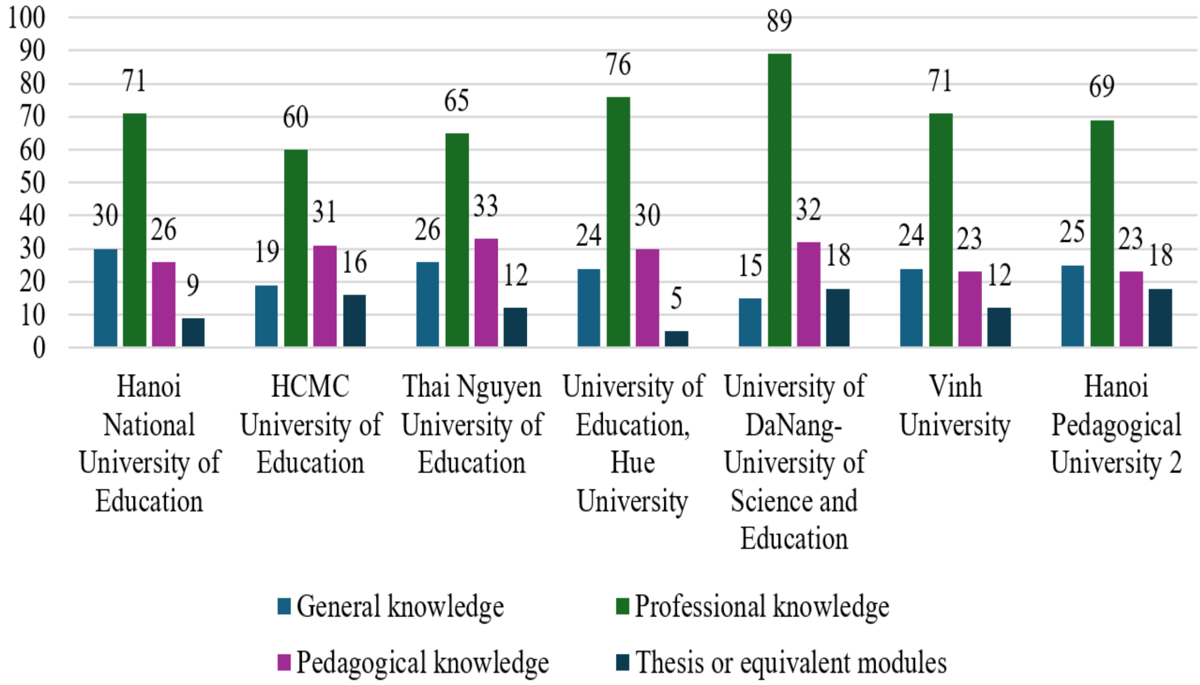

Figure 3. Number of credits in each knowledge block in the mathematics teacher training program of seven Pedagogical universities.

Through a comprehensive analysis of each knowledge block, the general knowledge is similar across these universities because they all contain philosophy, Marxism-Leninism, the ideology of the Communist Party of Vietnam, and foreign language courses (mainly English). The pedagogical knowledge block is designed with great similarities with courses on psychology, education, teaching theory, and professional practice. However, universities such as TNUE also include information technology in this knowledge block. The specialist knowledge block will include advanced Mathematics subjects such as algebra, calculus, arithmetic, and topology. In addition, some institutions like Vinh University integrate knowledge of information technology and STEM into this block. The dissertation block or equivalent modules provide students with the option of undertaking a dissertation or taking advanced Mathematics courses or courses that focus on Mathematics teaching methods. Overall, the training programs for Mathematics teachers at these seven core Vietnamese pedagogical universities demonstrate a clear alignment with the global trend in the design of training programs for teachers. However, these programs do not strictly adhere to the TPACK framework because the technology knowledge block is not clearly represented in the curricula. To further prove the assertion regarding the lack of emphasis on technology knowledge in Mathematics teacher training programs, we have calculated the percentage of credits allocated to IT and STEM courses compared to credits allocated to advanced Mathematics courses in the surveyed programs. Figure 4 depicts these results.

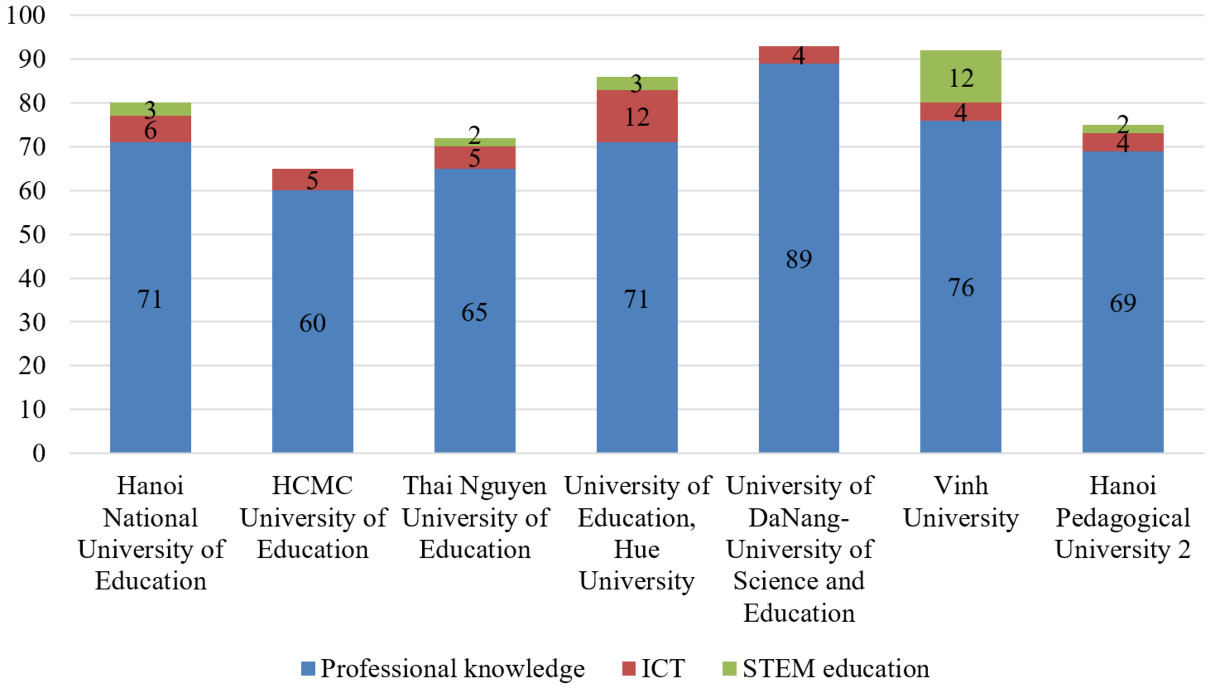

Figure 4. Number of credits for advanced mathematics knowledge, ICT knowledge, and STEM education knowledge in training programs of seven Pedagogical universities.

Our study indicates that the University of Science Education, an institution within Da Nang University, has the highest number of professional knowledge credit points, totaling 89. Conversely, Ho Chi Minh City's University of Education is ranked the lowest with 60. It is understood that institutions with a higher number of credit points for professional knowledge tend to allocate fewer credits to other knowledge blocks, particularly IT and STEM. This suggests that when developing training programs, these universities still prioritize professional knowledge over the integration of modern elements such as ICT or STEM education.

The number of IT credits in the training programs remains low in these institutions, except for Hue University of Education, which has twelve credit points. The number of credit points for STEM education also remains minimal, except for Vinh University, which offers twelve STEM credit points. On the other end of the spectrum is the University of Da Nang, which does not have any dedicated STEM courses in its curriculum. Such differences highlight the lack of consistency in integrating modern pedagogical elements into training programs for Mathematics teachers, showing a lack of priority for equipping future educators with essential knowledge.

In the context of 4IR and rapid AI advances, ICT and STEM are no longer merely complementary but now essential elements of training Mathematics teachers. ICT competencies equip new teachers with the ability to improve teaching quality, promote interactive learning environments, and make effective use of digital resources. Likewise, STEM education not only develops creative thinking but also helps students better prepare for future challenges in their careers. Therefore, ICT and STEM education need to be integrated more intensively into training programs to provide Mathematics-teaching students with vital skills and knowledge to succeed in teaching the subject in the context of 4IR. Vinh University currently has a commendable model of balancing traditional and innovative needs by increasing the proportion of ICT and STEM credits in its curriculum. This approach reflects the progressive vision that other institutions can adopt to modernize their curricula and better align with the changing educational landscape.

4.2. Discussion

Our study identifies challenges faced by mathematics teachers in the context of the Fourth Industrial Revolution (4IR) while also emphasizing the relevance of the TPACK framework in designing curricula to train a

Teacher 4.0. We also provide a comprehensive analysis of the status of mathematics teacher training programs in Vietnam within the scope of 4IR and the TPACK framework. The findings indicate that most training programs at leading pedagogical universities in the country lack ICT and STEM modules and do not sufficiently incorporate ICT in mathematics education. Even when such modules are included, they typically receive minimal credit hours and are non-compulsory. There is also a notable imbalance between the credits allocated to advanced mathematics modules and those for ICT and STEM courses. The absence of ICT knowledge modules and ICT applications in mathematics education may impede future teachers from effectively managing mathematics classrooms. Similarly, the shortage of STEM courses leaves future teachers underprepared to integrate mathematical knowledge with technological advancements in their teaching practices.

These findings are particularly noteworthy as they show that Vietnamese pedagogical universities have not fully recognized the challenges that 4IR poses for future Mathematics teachers. It also shows that the development of training programs at key pedagogical universities in Vietnam is still not closely aligned with the TPACK framework. This may affect the quality of teacher training and indirectly impact the overall quality of primary and high education in Vietnam in the coming years. Therefore, a major contribution of this study is to show the status of training programs for Mathematics teachers at Vietnam's leading pedagogical universities. Unlike previous studies, this study evaluates these programs from the dual perspective of the requirements of 4IR and the TPACK framework. This would have significant implications for pedagogical institutions as it emphasizes the usefulness of the TPACK framework in developing robust programs. The TPACK framework effectively integrates professional knowledge, pedagogical knowledge, and technological knowledge, equipping future teachers with essential competencies to overcome the obstacles of 4IR in Mathematics education.

However, this study is still limited in that it has only calculated the number of credit points in each block of knowledge in training programs without an in-depth analysis of the teaching strategies and methods used by lecturers at universities in the teaching process. It is essential to realize that students' IT competencies are not only developed through specific IT modules but also through the integration of IT into teaching activities within the faculty. Such limitations can reduce the comprehensiveness of findings. Despite these limitations, this study serves as an established foundation for further research.

Future studies should focus on the influence of faculty teaching methods on developing IT competency for pedagogical students. In addition, comparative analyses of curricula for mathematics teachers in Vietnam and programs in other countries can provide valuable insights. This expansion of the scope of research will help make more accurate recommendations for the Ministry of Education and Training and pedagogical universities regarding the design and administration of math teacher training programs.

5. CONCLUSION

In conclusion, this study identified the primary hindrance Mathematics teachers face in the 4IR context. The study also examined the feasibility of applying the TPACK framework in designing training programs to satisfy the requirements of the fourth wave of the Industrial Revolution. From these theoretical issues, the study highlights the imbalance between ICT and STEM courses and the current training programs for adequate Mathematics teachers at key pedagogical universities in Vietnam. The lack of ICT and STEM-focused courses can leave future teachers inadequately prepared for the knowledge and skills needed to teach effectively in the 4IR context. Our study offers valuable insights for universities in the country, as well as other institutions in other countries, to review and revise their teacher training programs, focusing on the design of compulsory ICT and STEM courses. Furthermore, the insights gained have laid the foundation for future studies, focusing on studying the impact of lecturers' masterful usage of ICT and the formation of ICT competencies in pedagogical students. While this study is not without its limitations, they do not diminish the overall contribution of the study. These findings are a significant step towards building teacher training programs that meet the requirements of 4IR.

5.1. Limitations and Future Research

Our research has limitations. Firstly, although the findings in our study stem from an analysis of training programs for Mathematics teachers at seven key pedagogical universities in Vietnam, it is essential to note that other universities are also involved in such training. Therefore, the conclusions drawn may not cover the entire context of this field in Vietnam. Secondly, the conclusions based on the analysis of these training programs do not provide sufficient evidence on whether Vietnamese Mathematics teachers fully meet the requirements of the 4IR. Therefore, in future studies, we plan to investigate the practical teaching competencies of these teachers, as well as their perspectives on how their teacher training programs have contributed to enhancing the pedagogical skills needed to fulfill the requirements of the 4IR.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
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Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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