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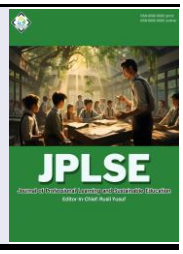

Mathematics teaching program to become a professional teacher in the digital era: Recent developments

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Abstract: This paper presents a systematic literature review aimed at exploring the initiatives undertaken to enhance the professionalism of mathematics teachers in the digital era. Utilizing Scopus as a source, we meticulously selected 7,570 articles based on specific keywords relevant to our research focus. Through a rigorous elimination process guided by defined criteria, we distilled these to 15 pivotal studies that specifically address the augmentation of mathematics teachers' professionalism. Our findings illuminate the evolving landscape of educational practices, particularly highlighting how educational practitioners are increasingly integrating technology to foster professional growth among mathematics teachers. This paper not only showcases various digital learning innovations but also offers a comprehensive analysis of the current state of mathematics teachers' professionalism, thereby contributing valuable insights into the intersection of education, technology, and professional development in the realm of mathematics teaching.

Keywords: digital era; mathematics teacher; teacher professionalism

Introduction

The progress and decline of a country is largely determined by the quality of education. Education has a big effect on a country's human resources (Dumciuviene, 2015). One of the components that makes education quality is channeled from teachers who are able to manage learning well (Pahrudin et al., 2016; Smith & Gillespie, 2023). This condition has been recognized because teachers are the key holders of programs and improving the quality of education (Oke & Fernandes, 2020; Sancar et al., 2021; Stronge, 2018). Teachers are tasked with designing (Wiliam & Thompson, 2017), managing (Dicke et al., 2015), implementing (Lawrence & Tar, 2018) and evaluating (Darling-Hammond, 2015) the learning process. These conditions make the participation provided by the teacher determine the success of the learning process. Apart from that, teachers are also involved in completing the bureaucracy set by the school (Koybasi et al., 2017). Bureaucratic burdens that are not balanced with quality requirements according to current developments can have an impact on learning outcomes in schools. According to several researchers, teachers are often busy with school administration and bureaucracy (Marrero et al., 2010; Stauffer & Mason, 2013) so that they are unable to meet professionalism needs.

Professional teachers certainly master the field being taught and how to teach it. The way of teaching is determined by the abilities and experience of each teacher (Andriani et al., 2018; Kini & Podolsky, 2016) therefore it is necessary to update any knowledge that has been obtained. Developing the quality of a teacher does not only involve formal education such as continuing studies. However, it includes all activities that are used for development and meeting educational needs (Hopkins, 2015). This self-development can be obtained through activities organized by the government (Shernoff et al., 2017) or by exploring information independently through various sources (Lin et al., 2017; Martín-Gutiérrez et al.,

2015). Fulfillment of various information regarding learning designs, how to assess results, providing guidance and training as well as carrying out service in the form of research will form professional teachers (Lee et al., 2015; Melnyk et al., 2019; Toropova et al., 2021).

Teachers' professionalism in teaching must keep up with the times. Likewise with learning media, currently many learning media are designed with the help of technology (Williamson et al., 2020; Zheng et al., 2018) and even use the presence of technology itself as the medium (Hadza et al., 2020; Puspitarini & Hanif, 2019). Such as learning using learning videos or using learning applications. The involvement of technology in learning can make it easier for teachers to teach (Azhari & Fajri, 2022; Lazar, 2015; McKnight et al., 2016) and make the teaching and learning process more enjoyable (Ahmadi, 2018). A fun learning process makes students more enthusiastic about participating in lessons (Chao et al., 2016). Teachers have a complex role in the digital era, this is because the role of teacher education continues to increase from being the main source of knowledge to being a role model to being entrusted by society as the main basis for determining the future.

As time goes by, of course, all aspects will develop and undergo transformation. Therefore, in order to be able to keep up with the changes that are occurring, teachers need to be equipped with the knowledge, skills, and competencies needed to transform education to meet the needs of society (Engelbrecht et al., 2020; Maass et al., 2019). Not only knowledge and skills in designing learning using technology but also in developing technology-based curriculum (Kaleli-Yilmaz, 2015; Misfeldt & Zacho, 2016; Yan et al., 2018). The conditions that must be achieved really challenge teachers to master it optimally, from knowledge about context to proficiency in operating technology (Drijvers, 2015) and creating attractive designs (McCulloch et al., 2018; Pepin, Gueudet, et al., 2017). The design created is not only to facilitate the learning process but is also ensured to make it easier for students to understand the lesson material (Kim & Cho, 2015; Saleh et al., 2018). All these things are done to become a professional teacher.

The skills possessed by professional teachers are obtained through practice and taking lessons from experience (Ekanayake & Wishart, 2015; Pennington & Richards, 2016; Rapanta et al., 2020). Professional teachers always try to provide the best quality version of themselves (Van Der Heijden et al., 2015) to maximize services against standards set by the government, and society and can improve students' abilities. Apart from cognitive abilities in the form of scientific and technical information, teachers also need to develop students' affective abilities such as attitude and mentality so that they are able to face the turmoil of very tight competition (Di Martino & Gregorio, 2019; Smedsrud, 2018). The development of teacher professionalism is largely determined by the extent to which the teacher recognizes his own abilities (Danijela, 2018; Shernoff et al., 2017). To recognize these abilities, there is a need to reflect on content knowledge and teaching practices.

Through reflection, teachers will find out how well the actions they have taken have been to meet standards (Gomez et al., 2015; Julie, 2015). Having this picture will help teachers choose the right solution to increase their professionalism. This condition also applies to mathematics teachers. Moreover, mathematics is often considered a difficult subject by students (Aljaberi, 2015; Fokides, 2018). Because of this assumption, students tend to get bored easily and are not enthusiastic about studying mathematics (Erdogan & Yemenli, 2019; Gafoor & Kurukkan, 2015). Mathematics teachers need to learn ways to understand mathematics that are easily accepted by students, one of which is by displaying visualizations of mathematics itself (Ruipérez-Valiente et al., 2015; Smilkov et al., 2017). Mathematics visualization can be obtained through displays of teaching aids, mathematics learning videos and applications that support mathematics material (Koparan, 2017; Saputra & Fahrizal, 2019). Therefore, mathematics teachers have a big burden to master all these needs so that they are able to act as professionals.

Teachers need to act professionally in carrying out their duties as teachers so that students are able to achieve the learning goals that have been set (Engelbrecht et al., 2020; Speer et al., 2015), therefore there is a need for breakthroughs to develop teacher professionalism so that they can form capable students. compete at international level. Based on research conducted by Merliza & Retnawati (2018), it is revealed that teachers have done many things to become professionals. However, teachers still have to increase their knowledge and skills to maintain their professional quality (Pardimin & Huda, 2018). They continue to improve their quality from time to time because

changes never stop. Such conditions require an overview of what teachers have done to increase professionalism and how the results of the actions they have taken have been achieved. Many studies have been conducted to examine the professionalism of mathematics teachers. Through this research, the researcher summarizes studies regarding professionalism. Readers will find out how far teachers have gone to improve their professionalism and what they are preparing to face in the digital era. The formulation developed in this research is in the form of:

1. What can be done to improve the professionalism of mathematics teachers?
2. What are learning innovations in the digital era?
3. How do you identify professional mathematics teachers?

Method

This research uses a systematic literature review (SLR) to present a comprehensive and complete summary of the latest mathematics teacher professionalism in the digital era. The analysis carried out refers to and is relevant to the research questions. Systematic literature reviews have analysis stages starting with identifying keywords to validate selected articles through citation techniques. Through this analysis, researchers can find out whether there are gaps in the selected articles between the research objectives and the results obtained.

The research analyzed is indexed by Scopus with the aim of obtaining accurate and more significant data. Keywords used when working in search engines are "teacher professionalism" "mathematics teacher" and "digital era mathematics teacher". The selected data is only writings in articles, while others such as books, news, theses, short articles, book chapters, non-article studies, and papers will be deleted at the reduction stage. The article selection process is carried out regularly so that no related articles are eliminated.

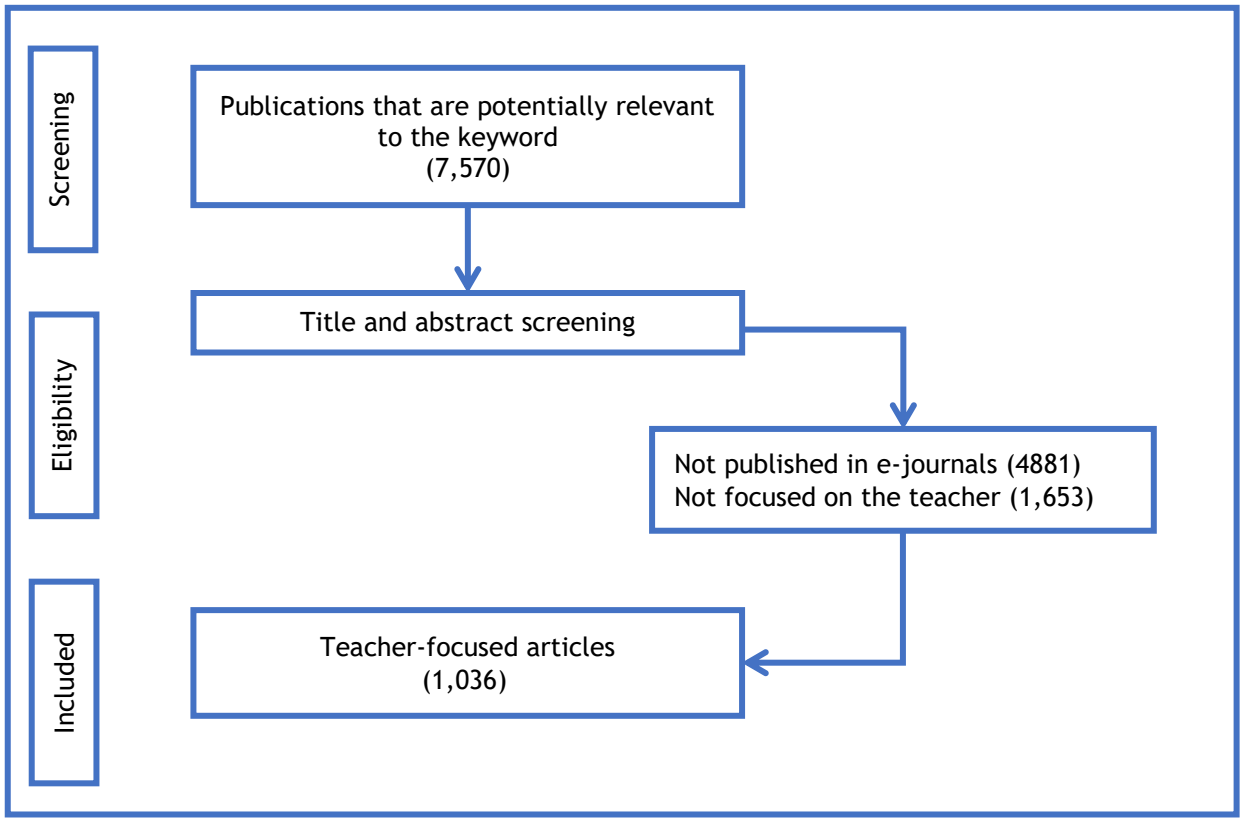

Figure 1. Diagram of a systematic literature review

After going through a long process, researchers detected 1,036 articles that studied the professionalism of teachers from various scientific disciplines. Furthermore, articles are selected that are only related to mathematics, anything other than mathematics will be eliminated altogether. There were 90 articles that studied mathematics teachers. 15 articles about STEM also appeared with the same keywords. During the elimination process,

researchers also found articles that studied increasing the professionalism of STEM teachers in general (Chang & Park, 2020). Researchers also found increasing professionalism of STEM teachers which were written as review articles (Hurley et al., 2023). All STEM articles were removed from the database, leaving 75 articles.

Result

The article elimination process has been carried out systematically. However, researchers still found articles that did not meet their needs. This research analyzed primary studies so 12 papers had to be removed from the data that had been collected. Then researchers also found research that involved teachers in creating learning videos but focused on student learning outcomes (Hogue, 2022), balancing high-achieving students with students who had problems with mathematics (Taylor et al., 2022) analyzing teachers' responses regarding applicable autonomy (Paradis et al., 2018) the abilities of students enrolled in advanced mathematics and physics classes (Lissitsa & Chachashvili-Bolotin, 2019) learning in Cloud-facilitated classrooms (Hu et al., 2020) the relationship between student achievement and student individualization and thinking relating it to instructional change using teacher data (Horn et al., 2015) mathematics learning videos which function as a source of restructuring teachers' conceptualizations regarding students' language practices (Marshall et al., 2023).

Analyzing teachers' perceptions of the in-service training courses and workshops they attended to improve their professionalism (Bennett et al., 2022; Mishal & Patkin, 2016; Mtetwa et al., 2015). Here they explained that many things were gained from this activity, but some of the teachers who took part in this training aimed to fulfill teaching administration or purely to increase their teaching knowledge in terms of content and practice. Bolyard & Baker's (2023) article is included in the database of mathematics teacher professionalism but in this case they analyze mathematics teachers' practices in conceptualizing leadership roles and the impact of their work on the school's deep interests in content and pedagogy. Comparing the relatively similar abilities of pre-service teachers and experienced teachers (Yang et al., 2021). The relationship between teacher characteristics and student mathematics achievement (Sadak, 2023).

Analyzing shifts in teaching practices before, during and after participating in professional learning communities (Chauraya & Brodie, 2017) in teaching statistics (Makonye, 2016) comparing cognitive and competency evaluations of professional teachers (Kaiser & König, 2019). Teachers' experiences when implementing a mathematics teaching reform approach that focuses on elementary school students (Treacy, 2017). Analyzing the difficulties experienced by teachers while teaching mathematics (Osei & Agyei, 2023) and experiences of failure in developing prospective mathematics teachers (Lutovac & Kaasila, 2022). A total of 30 articles were included in the search for the professionalism of mathematics teachers but examined their perceptions of pre-service programs, assessed teacher performance, explored pedagogical methods, analyzed teacher abilities and studied the experiences of mentors in pre-service programs. All of these studies were removed from the data to be analyzed until finally producing 15 studies that focused on studying programs implemented to improve the professionalism of mathematics teachers.

Tabel 1. List of selected articles from journals

Article	Executed program	Results obtained	Research sites
(Auslander et al., 2023)	Elementary Mathematics Specialists Preparation Program	Provides positive results in insight and teaching preparation that focuses on content and practice. Prioritize student-oriented pedagogy, be more confident in teaching, have the enthusiasm to continue moving forward so that you become a productive person and build capacity through interaction	Atlanta, US

(Capone et al., 2023)	Lesson Study between teachers and researchers	Confronting teaching practice, enriching professional development that can create didactic awareness both inside and outside the classroom	Italy
(Chan et al., 2018)	Lesson Study	Evidence-based optimization of teacher learning during design and instruction	Australia, China and Germany
(Dalby & Noyes, 2022)	Communities of Practice	Improving professional learning and developing the competence of mathematics teachers	Britian
(Fowler et al., 2023)	Epistemic Object	Supporting the development of teacher knowledge in accordance with their respective fields	Australia
(Karsenty & Arcavi, 2017)	VIDEO-LM project (Viewing, Investigating and Discussing Environments of Learning Mathematics)	Developing reflective language engages mathematics teachers to form in-depth discussions about the profession's core issues	Israel
(E.-J. Lee et al., 2019)	Noticing-Oriented Task Modification Activity (NOTMA)	NOTMA useful for developing teachers' abilities in designing and modifying mathematical tasks	Korea
(Makhubele, 2018)	The 1 + 4 Mathematics Teaching Intervention Programme	Make good decision-making policies, be able to design curriculum, and have higher content abilities than teachers in general. Developing a positive attitude towards teaching mathematics and increasing teacher competence in teaching	University in Texas
(Myers et al., 2021)	Prospective Elementary Mathematics Specialists' (PEMSs)	Authentic residencies and mentor sessions let faculty practice what they've learned. Then develop effective discourse so as to obtain more meaningful learning	US
(Pang, 2016)	Lesson Study	Create detailed learning plans, be able to face the complexity of teaching and develop the ability to utilize student ideas and open international dialogue regarding the development of teacher professionalism	Korea
(Philippou et al., 2015)	Continuing professional development (CPD) programme	Forming conceptualization and epistemology-oriented learning	Cyprus
(Taranto & Arzarello, 2020)	MOOCs (massive open online courses)	Stimulate research community discussion to build a shared understanding of the professional mathematics teacher education process	Italy
(Watters et al., 2018)	Classroom Videos	Strengthening the value of dialectical interactions focused on authentic mathematics teaching	Australia

(Yow et al., 2021)	Teacher Leadership Course	Teacher leadership develops as a professional mindset	US
(Yuan & Huang, 2019)	Mathematics Teacher Exchange Programme	The development of this program can improve the quality of education in western countries. Encourage the creation of mathematics books in English, form concepts and learning experiences from developed countries (China) and can guarantee the development of teacher professionalism	China and Britian

The 15 articles analyzed provide information that currently educational practitioners are starting to maximize the use of technology. The study was carried out involving technology ranging from learning media for teachers, tools used for experiments and even distributing instruments because the research was carried out on a large scale and some involved more than one country. Proficient in using technology is something that is really needed nowadays. The existence of technology makes it easier for researchers to revise and select samples with a large scope and without distance limitations. This allows researchers to select the sample that best suits their needs, thereby producing accurate research regarding the professionalism of mathematics teachers.

Discussion

Teaching skills can be categorized as one element of professionalism possessed by teachers. Every teacher has a different understanding of these skills. There are those who argue that teaching expertise is reflected by how reflective a teacher is, how creative and sweet they are (Kelly et al., 2015), there are also those who argue that a teacher's expertise is seen by how experienced they are in their field (Pepin, Xu, et al., 2017). Besides that, professional teachers also master teaching knowledge and the material taught. Even though mathematics has not changed conceptually, there are contemporary issues that teachers understand and can find common ground with mathematics material. So that students master mathematics with information about their environmental conditions.

Increasing the professionalism of mathematics teachers

Teachers are one of the shields to make students successful in learning school mathematics. Teachers also have a complex role in meeting students' needs to be able to solve various problems in their environment. Teachers have to do many things to be able to teach well, especially for beginners, they need to develop knowledge, skills and integrity (Sotiriadou et al., 2020). Beginner mathematics teachers need pedagogical knowledge in the form of content and teaching practices in order to be able to face various possible obstacles that occur in the classroom (Schatz Oppenheimer & Dvir, 2018). Getting these two things is not enough with what you learn at university. Beginning mathematics teachers need more input about pedagogy when starting to teach specifically referring to the level and field of study being studied. To achieve these teaching needs, of course teachers need pre-service programs that can increase the readiness of novice teachers (Norton & Allen, 2020). This includes in-depth mathematical knowledge as well as connecting to a variety of mathematical pedagogy.

Another thing that can be done to increase professionalism is to actively participate in research because through this teachers become aware of the most pressing issues regarding education (Sachs, 2016; Willegems et al., 2018). Besides that, teachers can also improve the learning process by habitually analyzing problems that occur in the classroom in depth (Gutierez & Kim, 2017). Being involved in research can increase knowledge because writing requires reading various related theories. From reading and writing, teachers learn more about what has been implemented in class and how to develop it to get better results. Through research teachers will also become familiar with various learning methods that can be applied (Roulston & Shelton, 2015). Varied and interesting methods can increase students' interest in learning so that the learning process ends well. Teachers and researchers can open up teaching horizons through research results so that they can be adopted as research-based

teaching innovations (Hollebrands et al., 2021). There are various reasons why research has a role in increasing the professionalism of mathematics teachers.

Learning Innovation in the digital age

Innovative education requires actualization to face the information era. So educational practitioners tend to introduce the implementation of innovative pedagogy in schools which aims to make it easier for students to adapt to the environment and be able to face challenges that arise (Alejandro & David, 2018). Innovative education forms a series of planned activities in a specific context, presenting the latest ideas aimed at improving students' abilities. One of the things teachers can do to help students develop following technological developments is to implement project-based learning (Sharples et al., 2016). Project-based learning focuses on the real actions that students take to master the lesson material.

Learning that focuses on real events can be realized with the role of professional teachers. In this case, teachers must be able to create a relevant curriculum that can optimize learning in the 21st century. 21st century learning is student-centered which focuses on students' interests and skill development (Dolezal et al., 2019; Feist & Reid, 2018). Apart from that, teachers must also teach and evaluate knowledge-based learning by utilizing Information and Communication Technology (ICT). Learning using student-centered ICT can foster interest in learning because it creates active and varied learning (Chen & Tsai, 2021; Eronen & Kärnä, 2018). Active and meaningful learning is used as an innovative conceptual breakthrough. This is not achieved instantly and easily but requires a learning process before teaching for teachers and is carried out in stages by continuing to reflect starting from curriculum design to student learning outcomes.

Identifying professional mathematics teachers

Self-identification is useful for knowing teaching abilities both in content and practice with the hope that they can be developed in areas deemed necessary to meet the needs and expectations of the teaching and learning process in the digital era (Ozmantar & Agac, 2023). Professional identity becomes an ongoing interpretation of experience, which can be realized from actions and teaching focus that refer to student needs. Professional identity is reflected in pedagogical and didactic ethics (Sardabi et al., 2018; Wald, 2015). To find out the extent of your identity, it is necessary to reflect on what has been done during the teaching process. Professional mathematics teachers need reflection to recognize weaknesses and improve strengths during teaching (Paulsen, 2015). One way to increase teacher reflection is to be driven by curiosity. Curiosity-driven can increase awareness of previously unnoticed events during the learning process, improving mathematical and pedagogical knowledge as well as teaching skills (Segal et al., 2023). Reflection can also be done with research using the COACTIV study. Through COACTIV (Cognitive Activation) it will detect teachers' cognitive activities in the classroom and literacy development (Bruckmaier et al., 2016).

Teachers who teach mathematics must update their teaching knowledge so that it can be conveyed well to students. Fennema-Sherman Mathematics Attitude Scales (FSMAS) can measure teachers' mathematical attitudes reliably and can be a tool for spreading the effectiveness of mathematics teacher professional development programs (Ren et al., 2016). Eichler et al., (2023) revealed that culture has relevance to the mathematics teaching and learning process. Many things in culture have a close relationship with mathematics. These conditions can be used as material to increase the coverage of mathematics material that is linked to local culture so that teachers and students can recognize their culture through a mathematical perspective (Lu et al., 2021). The process of exploring and understanding new information is one way to develop teacher knowledge regarding teaching content. Several articles that have been presented had to be deleted from the data base because they did not focus on actions that could improve teacher professionalism, but they looked more at the perspective of a professional mathematics teacher.

This research is limited to study programs implemented to improve the professionalism of mathematics teachers in general. It is hoped that future research will examine these programs in more detail so that they can truly be implemented to meet the needs of teachers in this digital era.

Conclusion

Students who graduate from university and start teaching still need pre-service programs to expand their pedagogical knowledge. The pre-service program being implemented currently

has adapted to technological developments. Teachers are starting to have an extraordinary awareness of mathematics education to develop their knowledge. Many of them are trying to improve their quality through conferences, collaborations, and publications, even internationally. The process of improving the quality of teaching cannot be separated from the characteristics of diversity that exist in each region. This diversity can give rise to various understandings and assumptions, so it requires government policies to provide space and limit it so that this diversity does not become an obstacle for teachers so that learning outcomes can be achieved according to expectations.

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