

Professional development of mathematics teacher: A systematic literature review

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Suggested Citation:

Rosli, R. & Aliwee, M. F. (2021). Professional development of mathematics teacher: A systematic literature review. *Contemporary Educational Researches Journal*. 11(2), 81-92. <https://doi.org/10.18844/cerj.v11i2.5415>

Received January 12, 2021; revised March 12, 2021; accepted May 28, 2021.

Selection and peer-review under the responsibility of Deniz Ozcan, Ondokuz Mayıs University, Turkey.

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Abstract

Implementing effective professional development (PD) programmes can help teachers in developing their knowledge and skills to enhance students' learning in the classroom. However, the PD programmes conducted have been seen as less helpful for teachers in developing their potential in teaching mathematics. This review aimed to explore the PD programmes for mathematics teachers and teacher components of an effective PD. This paper reviews 40 research articles from 2015 to 2020 from which such data were obtained from databases such as Google Scholar, Education Resources Information Centre and Springer. The findings show that the mathematics teacher PD programmes have been used to impact teacher attitudes and practices in classroom teaching practices, student learning outcomes and teacher knowledge and skills. It is suggested that more detailed research is supposed to be carried out to understand the impact of the teacher factors on PD programmes.

Keywords: Professional development, mathematics teachers, factors, systematic literature, databases.

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1. Introduction

Teacher professional development (PD) has been given more attention over the past decades. Gee and Whaley (2016) highlighted that the teacher PD programme plays a vital role in improving teacher knowledge. Besides, teacher PD programmes also required teachers to enhance their skills and understanding of the current education system. A qualified teacher plays a vital role in preparing the future generation for the country. A good teacher impacts student achievement and student character development (Bruckmaier, Krauss, Blum & Leiss, 2016). Darling-Hammond, Hyler and Gardner (2017) emphasise that teacher PD can enhance the level and aid in the teacher development process. Therefore, teachers need to be equipped with the latest knowledge and skills to improve their teaching.

Mathematics is an essential subject in school. Teachers always considered the mathematics subject as facts that need to be memorised and bring this impression into their instruction. As a result, the lack of mathematics proficiency can make students face difficulties in learning mathematics (National Research Council, 2001). The role of a mathematics teacher is to help students overcome the problems. However, for a teacher to help students develop mathematics proficiency, they must have a clear vision of teaching and learning in the classroom. Changes in the curriculum require a teacher always to change their teaching techniques and methods (Mellegard & Pettersen, 2017). Hence, teachers need to have ongoing learning to equip them with the latest knowledge and skills in the curriculum, using technology, and teaching practice. Auletto and Stein (2019) stated that teacher acceptance and PD readiness play an essential role in the education system's event. Mathematics teachers need to be equipped with knowledge (Heather et al., 2008) and excellent pedagogical skills (Lee et al., 2018) to lead an effective learning process. Effective PD programmes must be designed to enhance the level of teaching skills in the classroom. Various studies have been conducted to identify suitable PD programmes for mathematics teachers in improving teacher competence in teaching and learning (Tabach & Schwarz, 2018; Tan & Ang, 2016).

The primary purpose of this systematic review was to explore the mathematics teacher PD programme. In recent years, implementing a PD programme for mathematics teachers has been widened to benefit the teacher and emphasise its achievement and the organisation they belong to (Jacob, Hill & Corey, 2017). In general, all research types need to address a clearly stated objective to determine the study's direction. Therefore, the objectives for this systematic review are as follows:

- i. To analyse the mathematics teacher PD programme.
- ii. To identify the teacher's factors for an effective mathematics PD programme.

This review's conceptual framework is shown in Figure 1, and this framework is used to guide the analysis. This review's structure has been adapted from Desimone's (2009) conceptual framework by studying the effect of PD on teachers. An empirical study by Gore et al. (2017) showed that PD could affect teacher practice, such as the teacher's knowledge and skills, teaching practice and student learning outcomes. Furthermore, elements of this framework will help to identify the objective of this review through literature studies.

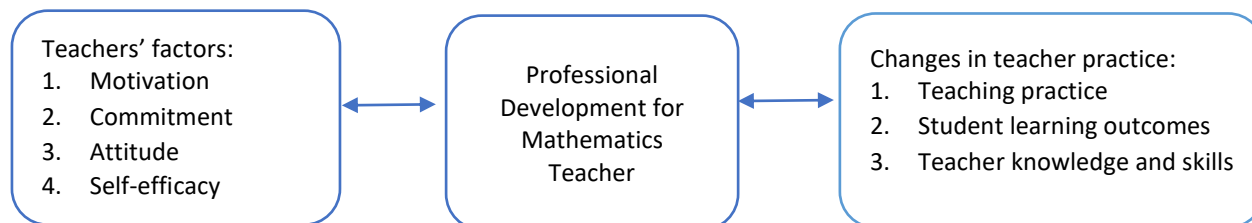


Figure 1. Modified conceptual framework from Desimone (2009)

1.1. Literature review

Mathematics is a subject that relates to numbers, measurements, quantities and shapes. Teaching mathematics cannot be conducted effectively without understanding knowledge, pedagogy and skills to be used in teaching and learning sessions (Oslund, 2016). As the technologies rise, mathematics teachers' methods to improve their teaching and learning process also grow. A study conducted by Aseeri (2019) shows that programmes and activities of PD for mathematics teachers should be designed based on the needs and experiences of the teachers. PD for mathematics teachers intended to equip the teacher with various pedagogical skills and become competent in the classroom. Hence, teachers need to attend the PD programme to improve their teaching techniques for better learning sessions. Effective PD programmes involve structural features, including activity formats, collaborative participation by teachers and duration of activities. On the contrary, useful core features include content knowledge, exciting opportunities for teachers to learn and coherent with other PD activities (Sevis, Cross & Hudson, 2017; Desimone, Burman & Yoon, 2002).

A practical PD model can change teachers' thinking and ability to enhance students' learning (Dogan et al., 2015). Darling-Hammond et al. (2017) state that the PD for mathematics teachers can be improved when the programme's design and implementation consider teachers' needs and wants in conducting classroom learning. A study conducted by Hatisaru and Erbas (2017) on the current state of teachers undergoing PD emphasises the relationship between quality teaching and student learning outcomes. Powell and Bodur (2019) discussed how PD programmes could influence teachers' perceptions and practices by focusing on specific teaching topics during the programme. As a result, teachers can increase their abilities and teaching practices in the classroom. In addition, Niess and Roschelle's (2018) study on the effects of teachers' teaching practice on students' achievement shows an increase in students' performance after the teacher attended a PD programme which focused on improving teaching practice. However, there is also a research conduct on teacher skills to provide better students' learning. Successful PD programmes should also impact teachers' knowledge and skills (Jacob et al., 2017). To ensure PD programmes' success, teachers need to increase their knowledge and skills towards curriculum innovation (Mellegard & Pettersen, 2017). Without knowledge and skills of current changes, teachers would face difficulty maintaining good teaching and learning sessions.

Factors of mathematics teacher's awareness towards the PD programme have been discussed in many studies (Heystek & Terhoyen, 2015; Vanassche & Kelchtermans, 2016). Studies have found several factors for teachers to ensure the success of PD programmes. For example, past research shows factors were involvement, including motivation in participating (Durksen, Klassen & Daniels, 2017; Han & Yin, 2016; McMillan, McConnell & O'Sullivan, 2016), commitment during activities (Avidov-Ungar, 2016; Chesnut & Burley, 2015; Cordingley, 2015; Whipp & Geronime, 2017), attitude during and after the implementation of PD (Mellom, Straubhaar, Balderas, Ariail & Portes, 2018; Troia & Graham, 2016; Van Aalderen-Smeets & Walma van der Molen, 2015) and teachers' self-efficacy on their ability to execute what have they learned in teaching and learning (Althausser, 2015; ; Yoo, 2016). However, all of these factors focused on mathematics teachers on the primary and secondary school levels.

2. Method and materials

2.1. Research design

The survey research's designs were made to synthesise the empirical study's findings related to the mathematics teacher PD programme. Guidelines for carrying out a systematic review in the social sciences from Petticrew and Robert's (2006) study were followed for this research. The guidelines contain four main stages, as shown in Figure 2.

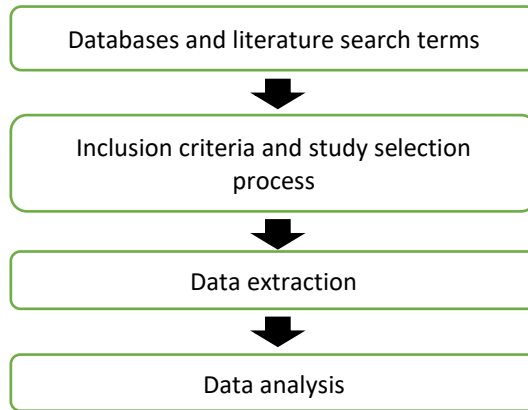


Figure 2. Stages of systematic review

2.2. Stage 1: databases and literature search terms

There are particular aspects that need to be taken into consideration when selecting articles. Only studies that met the requirement were included in this review. There were three databases, including Google Scholar, Education Resources Information Centre and Springer, being used to research up articles published between 2015 and 2020. The search of a scientific literature repository was conducted using several search terms. The search terms used were ‘professional development’, ‘professional development for mathematics teacher’ and ‘mathematics teacher programmes’. A total of 3,495 journal articles were found through this phase.

2.3. Stage 2: inclusion criteria and study selection process

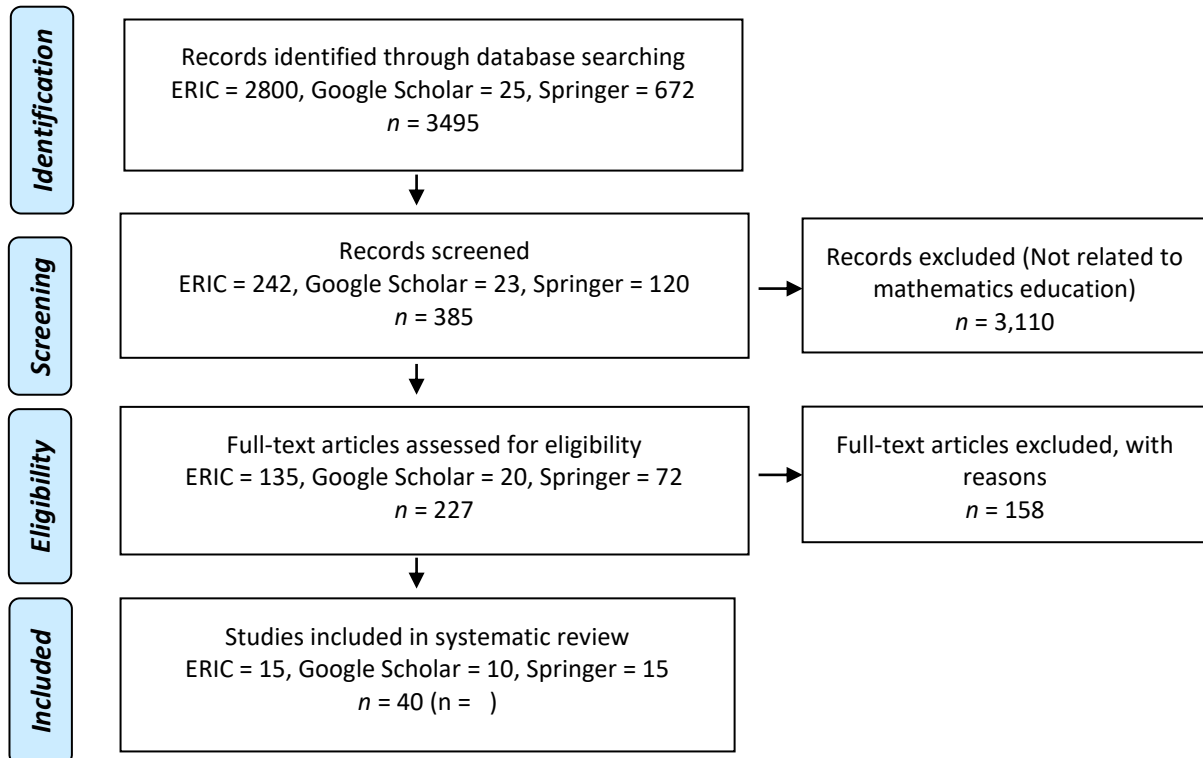


Figure 3. PRISMA chart

For these empirical articles to be included in this review, several criteria must be followed accordingly. The inclusion criteria for this review are as follows: (a) English peer-reviewed journal articles and conference papers; (b) published between 2015 and 2020 only; (c) available in full text; and (d) the participants were mathematics teachers. With regard to exclusion criteria, studies were excluded if there were a thesis, book or review research. The selection process is shown in Figure 3 by using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) chart.

The screening process of 227 articles from 2015 to 2020 identified only 40 pieces that had met the criteria for inclusion and contained the findings that focused on mathematics teacher PD.

2.4. Stage 3: data extraction

The relevant data were extracted to evaluate the articles' quality after the studies had been identified in the systematic review. Gast, Schildkemp and Van der Veen's (2017) suggested criteria for the data to be extracted from each article were as follows:

- i. General information: Title, author and year of publication, research context and journals.
- ii. Topic: PD programme for mathematics teachers.
- iii. Research design: Research questions or research objectives, description of the study and research design.
- iv. Overall results: Findings related to the research questions.

2.5. Stage 4: data analysis

The results and findings extracted from all empirical studies were gathered using structured summaries to answer the objectives. The findings and discussion parts of all articles that met the criteria were examined in further depth after extracting the articles' total results to ensure a detailed representation of the results. For this systematic review, a thematic analysis was carried out to analyse all the articles. The thematic analysis helped to analyse extensive data by grouping them into specific themes.

3. Results

The findings are discussed according to the two research objectives which are divided into several themes.

3.1. Mathematics teacher PD model

This section provides an overview of the PD programme's type and the impact of the mathematics teacher PD programme. The aim here includes creating a summary of the PD programme's impact, since they tend to have different characteristics and work differently. PD requires several types to ensure that teachers will continue to enhance their skills during the lesson. The findings presented in Table 1 show that past research utilised various types of PD programmes. Overall, the results showed that PD programmes were often conducted, such as seminars, conferences or workshops, followed by online courses, teacher observation, peer group discussions and short-term courses. The researchers' least PD programmes were adopting reflective and exploratory studies and individual reading or research.

Table 1. Types of mathematics teacher PD programme

Types of programmes	Articles
Online courses	Hill, Bicer and Capraro (2017), Martin, Polly, Mraz, and Algozzine (2018), Young, Young, Hamilton, and Pratt (2019), Huang and Manouchehri (2019), Beilstein et al. (2020), Bruckmaier et al. (2016), Chai (2019), Clark-Wilson and Hoyles (2019), Havard, Nguyen and Otto (2018), Polly et al. (2018)
Peer group discussions	Kul (2018), Gee and Whaley (2016), Tabach and Schwarz (2018), Tan and Ang (2016)
Teacher observation (mentoring)	Nel and Luneta (2017), Courtney (2018), Auletto and Stein (2019), Bozkurt and Ruthven (2017), Yopp, Burroughs, Sutton, and Greenwood (2019)
Short-term courses	Andersson and Palm (2018), Pournara and Barmby (2019), Lindvall (2017), Thurm and Barzel (2020)
Seminars/Conferences and Workshop	Carney, Brendefur, Thiede, Hughes and Sutton (2016), Darragh and Radovic (2019), Caddle, Bautista, Brizuela and Sharpe (2016), Dayal and Cowie (2019), Maher and Prescott (2017), Oslund (2016), Biccarrd and Wessels (2017), Biccarrd (2018), Sarama, Clements and Spitler (2017), Kutaka et al. (2017), Heck, Plumley, Stylianou, Smith, and Moffett (2019), Xie, Kim, Cheng and Luthy (2017); Yang, An, Lu, and Fan (2018)
Adopting reflective and exploratory studies	Pang (2016), Ni Shuilleabhain and Seery (2018)
Individual reading or research	Liang, Mira, Prasad and Patterson (2019), Galindo and Newton (2017)

The effect of these PD programmes can be divided into three main categories: (1) on teacher knowledge and skills, (2) on teaching practice and (3) on student learning outcomes. The results are shown in Table 2. According to Guskey (2002), an effective PD programme should significantly change the teachers' attitudes and beliefs. There are three main impacts discussed in the empirical studies. Throughout the study, teacher knowledge and skills play a vital role as teachers need to have better content knowledge to enhance pedagogical content knowledge (Kul, 2018). Besides that, Andersson and Palm (2018) stated that teachers need to shift their teaching practice towards learning based on student's needs. As a result, students learning outcomes were achieved as an effect of an appropriate and well-planned PD programme (Kutaka et al., 2017). Based on Table 2, out of 40 articles, 18 focused on the impact of PD on teacher knowledge and skills and teaching practice. In comparison, student learning outcomes became the least focused impact of the researchers, only contributing to four articles. Some studies revealed the two effects of mathematics teacher PD on their findings, for example, teaching knowledge and skills with teaching practice (Heck et al., 2019) and teaching knowledge and skills with students' learning outcomes (Hill et al., 2017).

Table 2. Impact of mathematics teacher PD programmes

Impact of the programme	Study
Teacher's knowledge and skills	Yang et al. (2018), Sarama et al. (2017), Pournara and Barmby (2019), Heck et al. (2019), Beilstein et al. (2020), Tabach and Schwarz (2018), Tan and Ang (2016), Auletto and Stein (2019), Thurm and Barzel (2020), Xie et al. (2017), Carney et al. (2016), Darragh and Radovic (2019), Hill et al. (2017), Bozkurt and Ruthven (2017), Kul (2018), Dayal and Cowie (2019), Young et al. (2019), Huang and Manouchehri (2019)
Teaching practices	Biccarrd and Wessels (2017), Biccarrd (2018), Sevis, Gee and Whaley (2016), Ni Shuilleabhain and Seery (2018), Bruckmaier et al. (2016), Courtney (2018), Yopp et al. (2019), Galindo and Newton (2017), Andersson and Palm (2018), Chai (2019), Caddle et al. (2016), Martin et al. (2018), Clark-Wilson and Hoyles (2019), Nel and Luneta (2017), Liang et al. (2019), Maher and Prescott (2017), Oslund (2016), Pang (2016)
Student learning outcomes	Kutaka et al. (2017), Lindvall (2017), Polly et al. (2018), Havard et al. (2018)

According to Guskey (2002), an effective PD programme should require an essential change in teachers' attitudes and belief. There are three main impacts discussed throughout the literature studies. Throughout the study, teacher knowledge and skills play a vital role as teachers need to have better content knowledge to enhance pedagogical content knowledge (Kul, 2018). Besides that, Andersson and Palm (2018) stated that teachers need to shift their teaching practice toward learning based on student's needs. As a result, students learning outcomes were achieved due to an appropriate and well-planned PD programme (Kutaka et al., 2017). Based on Table 2, out of 40 articles, 18 focused on the impact of PD on teacher knowledge and skills and teaching practice. On the contrary, the researcher's student learning outcomes became the least focused, only contributing to four articles. Some studies combine the two impacts of mathematics teacher PD on their findings such as teaching knowledge and skills with teaching practice (Heck et al., 2019) and teaching knowledge and skills with students' learning outcomes (Hill et al., 2017).

3.2. Teachers' conditions for an effective PD programme

This section described teachers' factors for an effective PD programme. Four factors were affecting the implementation of a PD, including (1) teacher's motivation, (2) teacher's attitude, (3) teacher's commitment and (4) teacher's self-efficacies. The first factor is the teacher's motivation during the PD programme. Eleven articles focused on teacher's motivation when participating in PD programmes and the relationship with teachers' learning (Biccard & Wessels, 2017; Darragh & Radovic, 2019). Ten articles also discussed teacher commitment throughout the PD programme. Teachers must commit to change according to the new idea in teaching and learning (Dayal & Cowie, 2019; Martin et al., 2018). Besides that, the teacher's attitude plays a significant role in effective PD. Although the change of teacher's attitude towards the implementation of PD may contribute to a better outcome, the teacher's perspective before attending a PD programme was the prerequisite for a successful result (Havard et al., 2018). The last factor is the teacher's self-efficacy. Teachers' perceptions about their ability to effectively deliver the instruction from a PD programme will influence students' learning outcomes (Carney et al., 2016).

Table 3. Teachers' factors for PD programmes

Factors	Study
Motivation	Biccard and Wessels (2017), Sarama et al. (2017), Andersson and Palm (2018), Darragh and Radovic (2019), Caddle et al. (2016), Kul (2018), Beilstein et al. (2020), Bozkurt and Ruthven (2017), Bruckmaier et al. (2016)
Attitude	Yang et al. (2018), Biccard (2018), Kutaka et al. (2017), Ni Shuilleabhain and Seery (2018), Liang et al. (2019), Pang (2016), Chai (2019), Clark-Wilson and Hoyles (2019), Havard et al. (2018), Kafyulilo, Fisser and Voogt (2016)
Commitment	Gee and Weely (2016), Pournara and Barmby (2019), Martin et al. (2018), Dayal and Cowie (2019), Nel and Luneta (2017), Young et al. (2019), Oslund (2016), Lindvall (2017), Tabach and Schwarz (2018)
Self-efficacy	Sevis et al. (2017), Courtney (2018), Carney et al. (2016), Hill et al. (2017), Maher and Prescott (2017), Huang and Manouchehri (2019), Auletto and Stein (2019), Heck et al. (2019), Polly et al. (2018)

4. Discussion and conclusion

The purpose of this systematic literature review was to synthesise empirical research on mathematics PD. This review focused on a few aspects of mathematics teacher PD, including types, the impact and teacher's factors affecting mathematics PD programmes.

This review's first objective was to analyse the mathematics teacher PD programmes in previous selected studies. During the analysis, the researchers clearly stated that they used several PD types when conducting the programme. According to Nel and Luneta (2017), there are no specific PD

programmes for all teachers because the key to success is teachers' engagement. It is believed that PD programmes provided teachers with the necessary knowledge and pedagogical skills so that they can apply them in their classrooms. For teachers undergoing PD combined with the experience, it will impact their teaching and learning styles (Courtney, 2018) and students' learning outcomes (Stein, 2019). Throughout the review, there were three main impacts of the PD programmes on mathematics teachers: teacher knowledge and skills, teaching practices and student learning outcomes. Mathematics teacher PD seems to have the most significant impact on teacher knowledge and skills, followed by teaching practice changes while less impacting student learning outcomes. Hill et al. (2017) found that teachers who attend PD programmes will enhance their content knowledge and their skills towards integrating technology for teaching mathematics in the classroom. Moreover, teachers' teaching practices in school increased as teachers participate in PD that focuses on pedagogy (Pang, 2016).

The PD programmes aimed to make changes in mathematics teacher knowledge and skills, their pedagogical content knowledge about mathematics and student thinking and teacher ability to incorporate all of this knowledge to evaluate mathematics teaching and enhance their teaching practice (Oslund, 2016). From the selected empirical studies, it can be seen that not all PD programmes designed for mathematics teachers were focused on student learning outcomes. However, Hill et al. (2017) stated that the effect on students' learning outcomes can be achieved after acquiring new knowledge and skills by the PD programme teacher. Based on the findings, we propose that PD programmes significantly affect teaching practices and contribute to student performances. Mathematics teacher PD programmes influenced the teaching and learning in the classroom in improving mathematics learning for students (Carney et al., 2016; Tabach & Schwarz, 2018; Yopp et al., 2019) and understanding students' way of thinking (Polly et al., 2018). In addition, through effective PD, teachers can build meaningful content knowledge (Thurm & Barzel, 2020; Xie et al., 2017) and support teachers in improving their mathematics teaching practice (Gee & Whaley, 2016; Pang, 2016).

The second objective is to identify teacher's factors for effective mathematics PD programmes. Four main factors were identified from the selected studies: teacher's motivation, attitude, commitment and self-efficacy. Andersson and Palm (2018) stated that teacher motivation towards the PD programme is significant as it affects morale and may influence their decisions to implement what had they learned throughout the programme. Teachers with high motivation are essential and can use the knowledge they gained from PD to overcome their student's difficulties in mathematics (Bozkurt & Ruthven, 2017). As a result, it encourages teachers to be entirely motivated throughout the PD programme. Besides that, effective PD also requires teachers' commitment to the programme as a committed teacher tends to integrate what they have learned effectively and demonstrate into their teaching practices (Gee & Whaley, 2016). A dedicated teacher is always aware that PD plays a vital role in their teaching profession. Committed teachers know that what they have learned will help them to enhance student mathematics achievement and continue developing a meaningful learning session in the classroom.

The success factor of a PD is highly dependent on a teacher's positive attitude as they help the teachers generate their knowledge and skills (Robertson & Daane, 2017). However, the success of the PD programme is always linked to a teacher's positive attitude. This is because a positive attitude will boost a teacher's confidence and develop them towards becoming a good mathematics teacher. The final factor is a teacher's self-efficacy, which is very important as teachers gain self-confidence to facilitate their learning (Rutherford, Long & Farkas, 2017). They join to enhance students learning outcomes (Gunter & Reeves, 2016). When teachers believe in their potential to teach and gain knowledge that can improve and develop their instruction, they are eager to participate in PD programmes because it will help them. Mathematics teaching and learning in the classroom can only happen when teachers want to change themselves, and the PD programme only can impact their knowledge and skills to a certain extent.

In sum, the quality of teaching and learning mathematics depends on teachers who are motivated, committed, positive attitudes and have high self-efficacy. Therefore, for enhancing the quality of

mathematics teachers, a teacher PD programme must be created for them. PD must be seen as a method for teachers to reform. It must be conducted as an ongoing process and to cater to the students' learning needs.

5. Recommendation

This review has shown that PD for mathematics teachers significantly impacts teaching practices, knowledge and students' learning outcomes. This review has also demonstrated that stakeholders such as government officials and policymakers or those inside the school should give more attention to the impact and factors contributing to teachers' learning outcomes when designing the programme. Future research is suggested to conduct a more extensive scale of quantitative and qualitative studies that required in depth analysis of other PD types for mathematics teacher such as teacher team-based, teacher collaboration or teacher communities' PD. Although some of the factors towards the success of PD programmes have already been identified, it is still questionable whether additional factors exist or all the factors mentioned are reasonably significant. Thus, it is suggested that more detailed research is supposed to be carried out to understand the impact of the teacher factors on PD programmes that have been pointed out from this review. Future research should also focus on providing vital information and reliable added values in teachers' knowledge building. Most of the studies only report the general findings on the teacher learning outcomes after implementing the programmes. However, those studies often did not provide detailed information on learning outcomes; for example, the articles only mentioned new knowledge and strategies learned without focusing on the practices' characteristics. Therefore, it will be interesting for future researchers to understand teachers' practice nature by discussing the connection between PD programmes' impact on individual, team and school organisation.

Acknowledgement

The authors would like to acknowledge the National University of Malaysia for the GG-2019-015 and GGPM-2013-085 grants supporting the research work.

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