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Factors that foster and deter STEM professional development among teachers

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Abstract

The present study seeks to identify teachers' perceptions regarding STEM teaching professional development and to identify the factors that facilitate or hinder the success of teachers' professional development. The participants of the study were 35 teachers. A qualitative approach was used for data collection by conducting semi-structured interviews with 11 teachers out of 35. All the participants were involved in the three focus group sessions. The findings of the study revealed that teachers have various perceptions toward the STEM professional development based on their experience, knowledge, and skills. Moreover, the study revealed different factors influencing STEM professional development among teachers including personal characteristics and internal factors including attitudes and beliefs toward STEM professional development activities, and teachers' capacity. Also, external factors such as design of the training program, availability of training material, and timing of training. The findings of the study could benefit the decision-makers to be aware about these factors that influence professional development and the teachers' needs.

KEYWORDS

external factors, internal factors, professional development, STEM

1 | INTRODUCTION

Integrating Science, Technology, Engineering, and Mathematics (hereafter STEM) is considered necessary to bridge discrete disciplines by using applications or processes from each one to construct knowledge and skills (Morrison, 2010). STEM education is crucial to providing citizens with the competencies to be successful in the era of technology (National Society of Professional Engineers, 2013).

STEM itself is not a new phenomenon, but the effort to reach learners with different backgrounds and different interests is new. In the last few years, there has been a huge increase in the number of STEM-focused schools in the Middle East such as Turkey (Baran, Canbazoglu Bilici, Mesutoglu, & Ocak, 2019; Malone, Helmer, Namyssova, Assanbayev, & Yılmaz, 2019) and the Arab world (El-Deghaidy, Mansour, Alzaghibi, & Alhammad, 2017; Wang, Hajjar, & Cole, 2020). STEM has evolved into a pipeline in which teachers are not the only information sources or distributors; a STEM approach enhances the student-centered approach and lets students be active learners (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012). Many educational systems in different countries integrate STEM education to enhance the quality of learning and literacy development (Gamse, Martinez, & Bozzi, 2017). Previous studies revealed that STEM could improve higher-order thinking skills, collaboration with peers and students' knowledge and skills, and prepare students for future jobs (Chachashvili-Bolotin, Milner-Bolotin, & Lissitsa, 2016; ChanJin Chung, Cartwright, & Cole, 2014; Kurup, Li, Powell, & Brown, 2019).

Implementing STEM in middle schools and K-12 classrooms introduces crucial obstacles for teachers, including steep learning curves and the discouraging task of gaining skills, knowledge, and confidence at guiding students through various activities (Parker, Stylinski, Bonney, Schillaci, & McAuliffe, 2015). Professional development (PD) programs focus on increasing teachers' knowledge, skills, and comfort with using technology in creative ways to increase integration of STEM in classrooms (Gamse et al., 2017; Khlaif, Gok, & Kouraïchi, 2019; Parker et al., 2015). Salha and Abu Sara (2019) mentioned that teachers used STEM to deepen their experiences and to teach using several tracks and approaches. Teachers were able to demonstrate their understanding and modified their knowledge by participating in small STEM projects. Ejiwale (2013) claimed that STEM education leads to new roles for teachers and that these new roles are not familiar. STEM teachers are required to adopt new approaches from the disciplinary approaches they were prepared for. STEM teachers would need to have the content knowledge and professional attributes to organize authentic STEM projects for their students, so teachers need certain personal and professional traits in addition to the deep knowledge about a broad range of content areas, pedagogical skills across disciplines, and access to appropriate resources (El Nagdi, Leammukda, & Roehrig, 2018; Salha, Affouneh, & Khlaif, 2019). Slavit, Nelson, and Lesseig (2016) described the STEM teacher as a "complex mixture of learner, risk-taker, inquirer, curriculum designer, negotiator, collaborator, and teacher" (p. 7). Teachers showed some resistance and it was hard for them to engage in STEM training.

The current focus on STEM subjects and careers in the Arab world, particularly in Palestine, has led to a proliferation of various outreach activities for students of all age groups. Some of the outreach activities have come from nonprofit organizations, the Palestinian Ministry of Education (MoE), and local companies. Some of these activities have been government-funded, and others paid for by participants. Different outreach activities have been implemented since the call of the MoE to implement STEM education, including interactive STEM workshops for teachers and for students of different ages, training on robotics, engineering activities, Poly up, programming, visits to industry, sports activities, competitions, and consultation activities about STEM integration. The purpose of these activities was to make STEM subjects fascinating and appealing to both students and teachers. Furthermore, these activities have been intended to augment and enrich students' learning experiences and to expose them to areas of STEM (Aslam, Adefila, & Bagiya, 2018; Hargreaves, 2010; Parker et al., 2015; Straw & Macleod, 2015; The Ministry of Education & Higher Education, https://www.nspe.org/resources/pe-magazine/recent-issues/2013-06). Practitioners include representatives of professional institutions, universities, nonprofit organizations, and volunteers who provide invaluable opportunities for students to engage in real-world problem-solving.

Teachers are expected to act as coordinators and facilitators of STEM activities, but they receive little training in how to manage and engage in such activities, whether these are formal or informal.

Shifting to interdisciplinary teaching is a significant challenge for teachers, and there is a need to prepare them for this shift. Teachers need to develop attitudes, skills, and knowledge to succeed in this change. PD is the key to helping teachers through the transformation process (Al Salami, Makela, & de Miranda, 2017).

To foster students' interest in and positive perceptions of STEM, teachers need to change their attitudes and beliefs to be enthusiastic about multidisciplinary teaching, collaborations with their peers and sharing strategies (Al Salami et al., 2017; Thibaut et al., 2018).

Daugherty and Carter (2018) defined interdisciplinary STEM education as a pedagogical approach where students learn how to connect different disciplines of STEM. Therefore, in the current research, “STEM education includes approaches that explore teaching and learning among any two or more of the STEM subjects, and/or between a STEM subject and one or more other school subjects” (Sanders, 2009, p. 21). Furthermore, interdisciplinary STEM education emphasizes analysis, synthesis of skills, and the content which promotes meaningful inquiry through generating ideas, creating, testing prototypes, and solving real-world problems (Sdunekv & Waitz, 2017). To summarize interdisciplinary approach, concepts from different disciplines can be integrated to generate new ways of thinking.

In contrast, multidisciplinary STEM education focuses on knowledge from various disciplines (Science, Technology, Engineering, and Math), concepts of each discipline can be used to clarify specific parts of a complex problem (Rogers, Pfaff, Hamilton, & Erkan, 2015). For the purpose of the study, we adapted *interdisciplinary* STEM education as a suitable approach for teaching students to allow students to generate new thinking approaches.

2 | RESEARCH PROBLEM

STEM education depends on integrating STEM subjects through an instructional method that uses designed-based, problem-solving, discovery, and exploratory, and learning strategies (Michalow & Road, 2015). So, that requires teachers to use new teaching methods and a deep understanding of STEM topics.

The absence of learning experiences in STEM subjects, lack of STEM teachers' development, and lack of high-quality STEM teachers, are the major obstacles in implementing STEM education in classrooms (El-Deghaidy et al., 2017; Watermeyer & Montgomery, 2018). Those obstacles could be also the important challenges of integrating STEM education in the Palestinian educational systems. It is difficult for teachers to shift from traditional teaching strategies to new teaching methods like STEM education that they have not experienced before (Toma & Greca, 2018). Furthermore, teachers need design skills to design classroom activities based on inquiry for STEM education (Watermeyer & Montgomery, 2018). Insufficient access to resources, lack of instructional support, lack of development opportunities, and lack of confidence could negatively influence STEM teaching (El-Deghaidy et al., 2017).

In an attempt to reduce these lacks, the Palestinian MoE called for exploratory summer STEM clubs. There were also calls from universities and nonprofit organizations for teachers to volunteer as facilitators and coordinators in these clubs. Many professional workshops were conducted to equip the volunteers with essential skills in STEM education, so that they could implement interdisciplinary activities. Identifying the factors influencing the PD programs plays an important role in mitigating these challenges and enhancing teachers' engagement in STEM teaching. To promote STEM education, the present study seeks to identify teachers' perceptions regarding STEM teaching professional development (STEM PD) and to identify the factors that facilitate or hinder the success of that PD.

3 | LITERATURE REVIEW

3.1 | PD of teachers

Teachers' PD is considered a capacity-building practice that can support teachers to be agents of change in the educational system to achieve the desired student learning outcomes (Brophy, Klein, Portsmore, & Rogers, 2008;

Phillips, 2008). PD is used to teach educators to change their attitudes toward using new methodologies or technologies in their practices (Honey, Pearson, & Schweingruber, 2014; Michalow & Road, 2015). Teachers play a crucial role in identifying the best approaches to STEM integration in classrooms (Michalow & Road, 2015). They need to understand STEM to have confidence in teaching it in a way that is integrated, interdisciplinary, and connected to the real world (Kurup et al., 2019).

PD programs are the cornerstone of all kinds of educational change (Fore, Feldhaus, Sorge, Agarwal, & Varahramyan, 2015). PD is a vehicle that can equip teachers with new skills and knowledge that qualify them to be agents of change in the educational system (Choy & Chua, 2019). The work of enhancing their subject knowledge, pedagogical knowledge, and skills to teach in interdisciplinary environments is very demanding. Many researchers have pointed out that there is a need to explore methods for assisting teachers to develop the necessary skills and knowledge to use STEM in classrooms (Brophy et al., 2008; Custer & Daugherty, 2009; Honey et al., 2014). PD enables teachers to build possible capacity to teach STEM with confidence and competence in their future careers (Kurup et al., 2019). When beginners participate in hands-on STEM learning experiences, they develop increased confidence and self-efficacy as STEM teachers (Custer & Daugherty, 2009; Honey et al., 2014).

Kurup et al. (2019) emphasized the need for preservice teachers to have PD and training courses that provide them with STEM expertise. It is necessary to formulate a course of work in STEM that integrates disciplines, provides understanding of pedagogical approaches, and is relevant with connections to real-life situations and 21st-century competencies.

Many STEM initiatives in different countries call for high-quality PD to cultivate teachers with necessary skills (Chai, 2019; DeCoito & Myszkal, 2018).

3.2 | Factors impacting teacher PD effective

PD is considered effective and has a positive impact on teachers when it focuses on the knowledge content, active learning, and congruent with other learning activities (Copur-Gencturk & Thacker, 2020).

Darling-Hammond, Hyler, and Gardner (2017) defined effective PD as structured professional learning that results in changes in teacher practices and improvements in student learning outcomes. And also Darling-Hammond found that the effective PD incorporates the following elements: PD that focuses on teaching strategies associated with specific curriculum content supports teacher learning within teachers' classroom contexts, incorporates active learning by engaging teachers directly in designing and trying out teaching strategies, supports collaboration by creating space for teachers to share ideas and collaborate in their learning, uses models of effective practice, provides coaching and expert support, offers feedback and reflection, is of sustained duration.

For the purpose of the study, the researchers defined PD effectiveness that teachers are satisfied with the training from different aspects including program design, availability of training material, time is appropriate, and the training environment is suitable. Many studies also identified the factors that influence PD in STEM. These include social climates and cultural practices in STEM; academic and social integration of students; academic sense of self (self-efficacy); sense of belonging; interpersonal relationships and expectations; and the attitudes and support of family, mentors, and peers (Moreira-Fontán, García-Señorán, Conde-Rodríguez, & González, 2019; Teo & Ke, 2014).

3.2.1 | Personal factors

Sprott (2019) found that teachers' characteristics play an important role in the development of their 21st century teaching skills and international competencies. In addition, Lunenberg, Dengerink, and Korthagen (2014) have identified critical characteristics concerning the PD of teachers and the particular behaviors in the roles of teachers, which are: context, building on personal qualities of the teacher educator, support, and research.

3.2.2 | Contextual factors

Furthermore, Chai (2019) explored the impact of the context on the effectiveness of the PD. In addition, the design of the PD program itself has an effect on the training of different participants. Ernst, Segedin, Clark, and Deluca (2014) emphasized that successful PD focused on improving student performance demands a deliberate structure and occurs within a well-organized and sufficient time frame. In addition, flexible, rigorous, and ongoing PD is recommended for creating positive changes in schools. Educators need learning experiences that foster demonstrable and sustained growth. Practices such as critical reflection and experimentation allow teachers to become learners, which fosters their applying new ideas and skills in their own contexts lack of STEM suitable infrastructure.

3.2.3 | PD design

Polgampala, Shen, and Huang (2017) stressed the importance of enhancing PD programs through sharing strong elements of leadership, building the capacity of teachers, and providing instructional guidance to teachers. In their study, the researchers emphasized the important role of participatory design in the PD process, also noting that teachers should have enough time to engage in PD activities. Margot and Kettler (2019) found that teachers confront several difficulties during STEM PD, including instructional challenges, separated subjects and textbooks, limited instruments for assessing STEM and anxiety about students' progress. It is important to contextualize PD in STEM topics based on current technological advancements that address the emerging needs of society, especially in the areas of green technology, elder care, biomedical science, the Internet of Things, artificial intelligence, big data, robotics, and unmanned automated vehicles (Lee, Chai, & Hong, 2019).

Moreover, Sprott (2019) mentioned that structural challenges of PD, as well as its "rigid hierarchical mandates," hinder collaborative opportunities among trainees (p. 325). In addition, the researcher indicated that appropriate time and space, as well as collaborative work, enhance teachers' training. Different factors have positive/negative impacts on the effectiveness of STEM PD, which could affect STEM integration in classrooms. In a recent study, Lee et al. (2019) found that teachers' capacity is one of the most important factors that influence PD, along with technological, pedagogical, and subject knowledge. Furthermore, teachers' perceived self-efficacy in STEM is affected by their integration into STEM PD.

4 | RESEARCH DESIGN

The primary aim of the study is to obtain in-depth information from those with lived experience in the field of study, which could be generalized and considered representative of that of the wider population (Creswell, 2007). Therefore, a case study approach was adopted for the study, as it enables exploration of teachers' wealth of knowledge, expertise in this field, and perspectives on the factors influencing STEM PD (Cohen, Manion, & Morrison, 2011). Two qualitative methods, semistructured interviews and focus group sessions were used to gather data concerning PD workshops and to achieve the purpose of the study.

4.1 | Research questions

As this is one of the first studies on STEM PD effectiveness in Palestine, the research questions focus on the following:

- What are teachers' perceptions of STEM education?
- What are the factors that make STEM PD effective?

The aim of the first question was to understand teachers' perception of their own experience about STEM education in the Palestinian context. Allowing teachers to express their perception and to talk about their stories with STEM education will allow us to explore the factors that influence teachers understanding of STEM education and the impact on their effectiveness to teach STEM which enhances our understanding of the second research question.

4.2 | Context of PD

A large university in northern Palestine has organized PD workshops on campus for teachers who are teaching different topics in middle school settings (fifth grade to ninth grade). The training conducted over two full days. The training sessions were in the morning and afternoon of each day. The objectives of the PD were to increase teacher's pedagogical knowledge to use different instructional strategies to STEM teaching and to equip teachers with appropriate skills to design STEM education activities. Supervisors from the Ministry of Education as well as professors from the Faculty of Educational Sciences and Training Teachers facilitated the sessions. The training materials and activities were developed by a computer science teacher who had experience in STEM education. An instructional designer revised the activities to make sure the activities aligned with the objectives of the training. Learning by design approach was used in the training sessions. With this approach, teachers have an opportunity to design STEM activities and learn how to implement interdisciplinary activities in classrooms.

4.3 | Participants

Teachers who participated in the training sessions were invited to participate in the study. Thirty-five of the invited teachers were agreed to participate in the study. The researchers interviewed 11 teachers out of 35 who agreed to participate (six females and five males). Three focus group sessions were conducted. Two focus group sessions were composed of 12 teachers and the third composed of 11 teachers. The focus group sessions had a total of 35 participants (24 females and 11 males). The teachers were from different backgrounds and teaching different topics and grades, participated on voluntary bases and devoted their time to working with students on STEM activities at An-Najah National University. As part of the study, they took part in three training workshops.

4.4 | Data collection

Semistructured interviews and focus group sessions were used for data collection. The interviews aimed to explore teachers' current experience with PD programmes and previous experience with STEM education. The interview questions were based on the research questions, and followed the procedures outlined by Seidman (2012). The interview protocol was developed to guide the researchers during the interviews. It consisted of nine open-ended questions and a series of probing questions that were used to extract more in-depth responses from participants.

The participants signed a form providing consent to record the interviews and the focus group sessions. Focus group sessions were held in the Electronic Learning Center at the university. The interviews were conducted for 30–45 min at the university or online using Skype and Zoom. Each focus group session ran for 1 hr.

In the focus group sessions, the researchers used prompts generated from teachers interview to have clear ideas from teachers through their discussion. For example, one of the prompts was “One of the teachers in the interview said that his study field in Bachelor does not help him to master the skills learned in the training, do you agree with him? Why? Please give examples from your teaching experience.”

4.5 | Data analysis

All the audio files were transcribed and analyzed based on Yin's (2014) procedures. Around 8 hr of recorded interviews and 2 hr of focus group sessions were analyzed by employing the constant comparative method suggested by Glaser and Strauss (1967) and cited by Corbin and Strauss (2015), as well as by using open coding by breaking down the text into small chunks based on an idea/concept in a statement. Furthermore, the researchers examined the notes from the training sessions observations, using a thematic analysis to identify data that enabled them to categories the factors influencing PD into themes and subthemes. In the first stage, they analyzed the interview responses to find out the patterns and group these patterns into categories. In the second, they organized the data from the focus group sessions based on these patterns.

The researchers found the pattern of the data by considering the frequency of an idea or a concept and categorizing it into themes and subthemes (Corbin & Strauss, 2015). The main themes were developed based on the most relevant ideas and concepts, repeated ideas, and concepts from different participants, or insightful statements in the focus group sessions and interviews. All quotes were related to specific themes, and subthemes used as evidence were reviewed separately. The constant comparative method involves an iterative process of revisiting the data and reconsidering its implications to increase validity.

5 | FINDINGS

By conducting a triangulation analysis between the data sources—semistructured interviews and focus group sessions—the researchers found that teachers have various perceptions toward the STEM PD. These perceptions are based on their experience, knowledge, and skills, as reported in the interviews and observed in the training sessions.

To answer the first research question, the findings were categorized in two main themes: positive attitudes and negative attitudes toward STEM projects. Video recordings and field notes on the interviews can be found in Khlaif (2020).

5.1 | Positive attitudes toward STEM PD

Most of the participants interviewed reported that they had positive attitudes toward the PD of STEM because it could help them to teach in STEM environments. One said that "I have new experience with STEM…Honestly, this [was] the first time to hear about it. Without training, I cannot integrate STEM" [ID-01].

Another female participant said, "I gained new skills to teach in STEM lessons" [ID-05].

Most new teachers who participated in the current study reported that they admitted the importance of teaching STEM. Those teachers demonstrated in the training sessions how they would teach their student in classrooms.

Females in the focus group sessions discussed their experiences of how they learned from the training sessions to teach in an interdisciplinary environment through integrating Science with Math. One of them mentioned that "[n]owadays different topics are intertwined together; for example, science and math…I think STEM can bridge the gap in teaching these topics" [ID-03].

Many male teachers consider STEM as an interdisciplinary practice, and they reported that they confront challenges in their daily work because they do not have enough experience to teach in this environment.

In the training sessions, the researchers noticed that teachers were confident and comfortable while they were implementing STEM activities. Some teachers in the focus group sessions reported that they would be confident in and enthusiastic about implementing STEM activities in classrooms. A follow-up question was asked about why they felt comfortable about implementing STEM. Teachers' answers were different based on their background, teaching topic, experience in teaching and gender. Some of them said “it was just expectation,” meaning they had no previous or current experience with STEM teaching. A female participant stated that she had experience in teaching Math for kids.

In addition, they considered STEM a high-value practice, even they were engaging with it for the first time, and their lack of preparation did not affect their positive attitudes toward it. Female teachers reported that they had positive attitudes toward STEM more and the researchers noticed that when some of the females explain the value of STEM education for them and for the students. One of them said, “STEM education taught how to connect different aspects of a real-life problem to solve it, not in education but in my social life.” Even the women have more social responsibilities due to taking care of her family and teaching, they were enthusiastic to teach with STEM. However, male teachers, who had negative attitudes toward it, with their justification being that they did not have enough time to prepare STEM activities. We noticed in the training sessions that females were more active in collaborating on and implementing activities than males.

The participants worked in teams in the training sessions, and reported in the interviews that the sessions encouraged them to work together to implement STEM activities. Some teachers connected their efficacy in using STEM to their comfort and confidence.

Two teachers reported that they had had negative perceptions of integrating STEM because they did not have a clear idea of how to teach in an interdisciplinary field, but that their perceptions had been changed after finishing the PD program.

> *Honestly, I [did] not like the idea at the beginning because everything was ambiguous, my supervisor told me, “We chose you to attend a training session about STEM”…It was the first time [I] hear[d] about it…My mind change[d] when we started to implement some activities.* [ID-02]

5.2 | Negative attitudes toward STEM PD

Males in the current study reported that they had social commitments with which the PD program interfered, but that their attendance was mandatory from the Directorate of Education.

> *I did not like this project [STEM]…In summer, I have many things to do. I am here because my supervisor nominated me to attend the training. I am not enthusiastic about the outcomes of training.* [ID-04]

Most of the participants claimed that they did not have experience with STEM and that they came to training when there was a voluntary call to participate.

Three participants (two males and one female) mentioned that their negative attitudes were due to their lack of capacity and insufficient skills to teach in an interdisciplinary environment. Some of the participants reported that they were frustrated with the STEM project because the training sessions were not providing them with clear procedures and activities to use in classrooms.

> *I thought training would be professional and I would be able to implement activities in classrooms, but unfortunately, training was unorganized [and] training environment were uncomfortable.* [ID-03]

In the training session, the participants reported that the quality of the training material was unsuitable for teachers to use. It did not follow any instructional design model, and most of the activities were translated from a different language. The participants in the focus group sessions also reported the weaknesses of the training material, suggesting it needed to be more interactive, to be suitable for different teaching topics and to provide different activities that meet individual needs (girls and boys).

> *The activities were insufficient and unsuitable for teachers' teaching fields…We have different ages from different backgrounds…I think the training materials fail to meet our [trainees'] needs.* [ID-05]

In addition, two females who have experience with STEM teaching reported that their negative beliefs toward STEM PD were due to the design of the PD program.

5.3 | Factors influencing STEM PD effective

The interviews and focus group sessions results indicated that teachers have different attitudes toward the effectiveness of STEM PD based on different factors. It was obvious to the researchers that the effectiveness of the STEM PD was influenced by various factors ranging from personal experience to the TD design.

Four main categories emerged that directly influenced the effectiveness of the teachers' PD program for STEM. These categories were teachers' personal characteristics, internal factors, external factors, and design factors. Figure 1 shows the relationships between the themes and subthemes related to STEM PD effectiveness, as reported by the participants.

5.4 | Personal characteristics

It was obvious to the researchers in the training sessions and in the focus group sessions that participants' personal characteristics, including gender, teaching experience, knowledge of the value of STEM education, and teaching topics played a significant role in engagement in the STEM training activities. Most of the female teachers were active in implementing the training activities and trying to find solutions for the challenges they confronted. For example, when the trainees were implementing an activity related to design engineering and science (creating a car that worked according to on Newton's third law) there was a lack of tools with which to complete the design, but one of the female teachers found a substitute solution which was using a recycled carton.

Teachers who have previous experience in teaching children using project-based learning and problem-solving approaches have more self-efficacy to benefit from STEM PD. One male teacher said: "I have basic skills to teach in STEM, but I need to get more skills and knowledge, especially related to designing suitable activities." [ID-06]

Many teachers reported that they were enthusiastic about participating in the training activities because they knew the benefits of teaching STEM and their students could acquire new skills in different topics in the same class.

> *I know the value of STEM for me and my students. Students can learn new knowledge and skills from real-life problems…I like to teach with STEM.* [ID-03]

In follow-up questions about the benefits and value of STEM and how teachers knew about those, participants mentioned that they knew from previous learning, reading about it on the Internet, and having had previous training out of the country.

The researchers noticed in the training sessions and focus group discussions that teachers who were teaching/specializing in technology engaged more in the training sessions than others. A follow-up question to those teachers about their engagement in the training. All of the technology asserted that their technical skills and computational thinking skills helped them to participate effectively in the activities in the training.

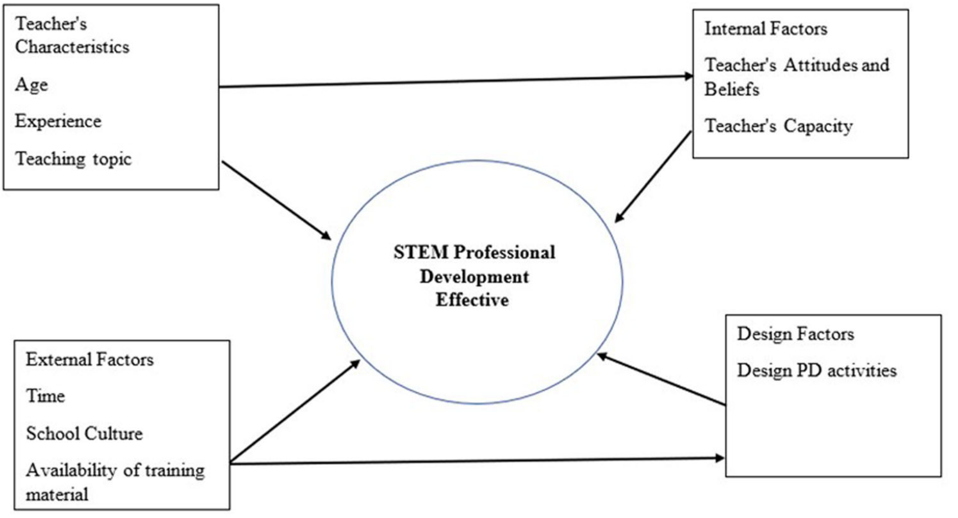

FIGURE 1 The relationships between the themes and subthemes related to STEM professional development effectiveness, as reported by the participants

5.5 | Internal factors

Analysis of different data sources revealed two factors important internal factors: attitudes and beliefs toward STEM PD activities, and teachers' capacity.

5.5.1 | Teachers attitudes

Most teachers who participated in the current study had positive attitudes toward and took part in in the training sessions. The researchers noticed that there were different factors affecting their attitudes, including the strategies the trainer used, the type of activities, and the timing of training. For example, in the afternoon sessions, participants did not engage in the activities as much as they did in the morning sessions. In response to a follow-up question about the timing of training, all the participants in the focus group sessions reported that the timing was not suitable, that it frustrated them, and that it prevented them from engaging fully in the activities.

> *I like to get training in STEM, but the time and location of training is not suitable for me and I cannot apologize because training is mandatory.* [ID-07]

Other teachers in the focus group session reported that their attitudes changed when they implemented some of the activities in the training session.

5.5.2 | Teachers' capacity

In the training sessions, the researchers noticed that teachers had different capacities to deal with the activities. Some teachers mentioned that they were hesitant and unable to engage in the activities because of a lack of knowledge and skills.

I am unable to engage in the activities due to my limited skills and knowledge; I hope that I can acquire new skills that could help me to use STEM education. [ID-08]

In the focus group sessions, participants discussed how their skills and knowledge affected their self-efficacy to engage in the activities. They raised different questions as prompts to discussion, such as "Why we use STEM?" and "What type of skills do we need to have to ensure successful of STEM education in classroom?" Participants provide different questions and talked about their experience. Males teachers discussed the negative side of using STEM and connected this to their skills and knowledge, which hinder them from using it. Answering a follow-up question in the focus group about why they did not enhance their skills and knowledge in STEM fields, all males answered "We do not have enough time to learn new things." One teacher justified not developing their capacity because the procedures of the Ministry of Education could cancel the project. A follow-up question was sent to the participant to elaborate his justification her answer was not allowing teachers to leave schools to attend the training and some training sessions were on the holiday day of the teachers.

5.6 | External factors

Participants in the study reported different environmental and contextual factors that could positively or negatively influence the effectiveness of the STEM PD. These were time, increases in workload, lack of financial and administrative support, the reluctance of teachers to collaborate, training materials, and the design of the PD program.

5.6.1 | Timing of training

As reported by the participants, the timing of the training sessions was one of the important factors that could impact the effectiveness of STEM PD.

Most of the female teachers reported that they like to be trained on new skills in morning sessions and do not prefer afternoon sessions because of their social responsibilities when their children come back from the schools. The researchers noted that levels of collaboration and engagement in the activities were higher in the morning sessions than in the afternoon sessions. However, most of the male teachers reported that they like to have training in the afternoon sessions.

The discussion in the focus group sessions focused on the benefits of training in the morning. Most male participants mentioned that they have additional work and social commitments in the morning, but few females prefer the training to be in the afternoon, as they must prepare their children before going out to the sessions.

5.6.2 | Changing the policy

Due to depending of the Ministry of Education in Palestine on funds from different donors, the policy of the MoE may be changed as mentioned by some of the participants.

Maybe the Ministry of Education will cancel or change it next year, as they did in many projects, like the smart learning project [and] e-learning. [ID-09]

5.7 | Design factors

5.7.1 | Availability of training material and activities

Teachers consider the availability of the training material and suitable activities as the major important factors that can make the training effective.

> *Sure, I cannot imagine that I am training on new skills or tools without training material…These materials should meet my needs.* [ID-10]

The training material was designed in a simple-to-follow format, and easy language was used to describe each activity. Each activity had its objectives and time scale, with clear guidelines and instructions.

5.7.2 | Design of STEM PD

The major factor that could influence the STEM PD was the design, which could be a third-order barrier to its effectiveness. This factor is related to designing effective activities to engage participants in the training sessions.

All the participants reported that the effectiveness of STEM PD depended deeply on the design of the training program. A follow-up question in the focus group sessions asked what participants meant by the design of STEM PD. Answers given by the participants included the timing of training, training materials, activities, training strategies, the scaffolding of trainees, and the training environment.

Some participants mentioned that they got frustrated by the weaknesses in the design of the training program. They mentioned that the training schedule and environment were unsuitable. Moreover, the length of the training was insufficient to equip teachers with basic STEM skills.

> *The length of training, training room, and the timing of the training were unsuitable for me and did not meet my needs.* [ID-011]

Some teachers critiqued the content of the training materials and the activities. One female participant said, "There nothing new in this material; I need something related to my teaching topic."

Most teachers in the focus group reported that the training activities did not hold their attention or encourage them to participate. A question about the design process for the training activities was directed to the trainer who designed the training materials. She mentioned that she had no idea about instructional design approaches required to create effective training material. In addition, she said, "translated most of the activities from a foreign language."

5.7.3 | Collaborative activities

Many teachers reported the importance of the teamwork among the participants in the training sessions. It helped to convey the skills and knowledge they learned in the training sessions.

> *I like to work within a group…I can learn from my colleagues; I do not hesitate to ask any question in the group.* [ID-06]

In the afternoon training sessions, the researchers noticed that most activities were teamwork, but teachers did not engage in the activities. In addition, engagement in the teamwork was based on the teaching topics, as indicated by the interviewers.

6 | DISCUSSION

As we have presented in Section 3.2, there a number of factors that influence PD in STEM: from academic and social integration of students to sense of belonging; from family support to social integration. Also the academic and personal context and the program design and the time frame (Chai, 2019; Ernst et al., 2014; Moreira-Fontán et al., 2019; Polgampala et al., 2017; Teo & Ke, 2014). This paper shows common factors found in those previous studies. For instance, the positive attitude toward the PD of STEM, the interdisciplinary practice, and the professional and social features (in addition to gender, as a personal factor). Also, they look alike on external factors like the timing of training or availability of resources.

Further, STEM activities are a significant tool for learning across the academic curriculum. The four main disciplines (Science, Technology, Engineering, and Math) combine practical and experimental approaches to understanding the world and solving problems. These four disciplines cannot work alone or isolated, as they need each other to build a common case for achieving specific competences. Math feed engineering, engineering feeds technology, and all of them together feed science, and vice versa. Quite often, they are complemented with Arts, becoming STEAM, which highlights the need for a more interwoven approach that supports cross-needs and cross-outcomes. Further, there needs to be a rational context in which to analyze and mutually support Science and Arts, so that creative thinking is strengthened by experimental thinking, which can be supported, in turn, with a less-structured flow.

Additionally, STEM is not just about the content. STEM is also about attitudes regarding how to combine different subjects and to find common ground that improves analysis, reflection, and concrete solutions to problems. STEM provides a multilateral way to meet objectives that leans on the principle of *super-summativity* or synergy, according to which two things working together are bigger and better than just the combination of those two things as a separate sequence (Fuller, 1982). This attitude also applies to finding STEM a good way for teachers to improve their lectures, their classrooms, and themselves. Through this approach, teachers can use another method to present content, problems, and ways to solve them. In doing so, they can also improve their teaching skills. Our research includes selected testimonies from teachers who find support in these subjects because they also need to update and learn from them in parallel. They also report that working on the problems together, in a collaborative way, makes them evolve and find different solutions than when they work alone. Furthermore, teachers mainly highlight two key internal factors: attitude and competence. Both define the usefulness and level of implementation of STEM in the classroom, which makes the experience very personalized and adapted to everyone's case. From the external factors, schedule, resources, design, and collaboration combined provide an adequate context for STEM, with a special emphasis on the availability of the material at the right time. The lack of provision of resources or their late delivery influences an appropriate implementation of STEM I the classroom.

Of course, we can always find negative attitudes about the required skills, the reluctance to change, the time to invest or the process. However, these attitudes can happen either with STEM or with other subjects, as they are part of human nature, irrespective of the matter at hand.

Thanks to this study, we find that STEM can become a key pillar to achieve competences and to develop teachers, enabling them to increase their professional expertise.

7 | CONCLUSION

A clear limitation of the current study is the sample size which hinders us from making generalization of the findings of the study to a larger population. In addition, the study depended deeply on self-reported data and we did not examine how this PD reflected on teacher's practice in classroom. A future study should include a mixed-method approach and include observation teacher's practice in the classroom. Furthermore, future research should focus on measuring teacher content knowledge assessments, students' achievements, and students' interaction with STEM activities.

With the recent pushes in the Palestinian educational system to infuse STEM education in public schools, preparation of teachers with the ability to integrate STEM education in classrooms practice becomes crucial for these efforts. It is important to invest in teacher's ability to help teachers provide the best quality in STEM practice in classrooms. To achieve this can be by teacher high-quality PD programs. Different factors revealed that can influence the success or failure of the PD. It depends on the characteristics of teachers, the institution policy, the designing of the PD program. Teacher's attitudes and beliefs toward STEM PD were important in the success of the training. Trainers can enhance teacher's attitudes and beliefs through collaborated activities and group work.

From this recent work, we can offer three implications for decision-makers in preparing teachers' programs as well as in the Ministry of Education. First, it is important to invest huge time in developing an effective PD program based on teachers' needs as well as providing scaffolding while implementing the training activities. Choosing the best time for training teachers is important and should be based on the teacher's choice, not the school's/ministry's choice. Second, it is important to design interdisciplinary activities and include teachers from different fields to represent teachers from IT, Science, Math, and Engineering. The third implication is that to support teachers in their schools through providing PD facilitators, and STEM experts close to the schools which could foster teacher's attitudes and beliefs toward STEM. Moreover, keeping open communication between teachers and training facilitators and experts could help to answer questions and solve emerging problems in implementing the activities.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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