

Sustainable professional development for STEM teachers in Saudi Arabia

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Abstract

This paper responds to the call for the need to develop professional development practices for leaders, supervisors, teachers, and student guidance within the framework of international standards, particularly in line with the Kingdom of Saudi Arabia's (KSA) vision 2030 (KSA, 2019). The current study aims to identify the obstacles and challenges for implementing sustainable professional development methods for teachers in KSA, who had participated in a ten-month Australian cross-national STEM professional development program. In addition, the teachers also participated in an immersion in Australian schools that lasted for 11 months. This paper reports on a sample of 22 male and female teachers coming from primary and secondary KSA schooling contexts. The participating teachers in the study were those who had participated in the Australian STEM immersion professional learning program in 2019-2020. Drawing from previous studies (Ermeling & Yarbo, 2016; Greene, 2015; Kayi-Aydar & Goering, 2019; Piqueras & Achiam, 2019), we have proposed a framework involving four methods for sustainable professional development for STEM teachers: professional learning communities, communities of practice, action research, and the outside expert. A mixed-methods research design was applied including three methods: individual interviews, open-ended questions to identify the proposed plan of STEM teachers' implementation of the sustainable professional development methods. Also, a questionnaire to identify obstacles to the implementation of sustainable professional development methods from the viewpoint of STEM teachers was also employed. The results showed that the most prominent obstacles to the implementation of the sustainable professional development methods by STEM teachers in the Saudi educational system where there is no coordination in the school meetings schedule for the members of the professional learning STEM education community, there is no clear plan for communities of practice of STEM education, teachers' overload teaching duties, lack of coordination between schools to benefit from STEM experts. Implications of our study reside in developing teachers' ongoing STEM professional development opportunities through execution of a sustainable model of collaborative teacher communities in KSA. Suggestions for curriculum stakeholders and administrator's coordination and supporting teachers' ongoing participation and implementation of professional development programs are discussed.

Keywords: professional learning communities, teacher communities of practice, action research, the outside expert, STEM professional learning

INTRODUCTION

The professional development of the teacher occupies a great deal of space in contemporary educational literature, due to its central importance in firstly developing, and then sustaining teacher knowledge and

skills (Darling-Hammond, 2010). This study responds to the call made by the Kingdom of Saudi Arabia's (KSA) vision 2030 (KSA, 2019), the human capital development vision realization program, which aims to improve the outputs of science, technology, engineering, and mathematics (STEM) education and training system at

Contribution to the literature

- The study contributes to the existing literature about professional development for STEM teachers in the Kingdom of Saudi Arabia, who had participated in a ten-month Australian cross-national STEM professional development program.
- The uniqueness of the study relies on combining the view of the development practices for leaders, supervisors, teachers, and student guidance within the framework of international standards, particularly in line with the Kingdom of Saudi Arabia's (KSA) vision 2030.
- The results showed developing teachers' ongoing STEM professional development opportunities through executing a sustainable model of collaborative teacher communities in KSA.

all stages from early education to continuous education. As such, providing STEM teacher training to maximize student achievement and lifelong learning opportunities in a bid to fostering students' 21st century skills. KSA vision 2030 also calls for creative ways to the development of all components of the education and training system, including teachers, trainers, faculty members, governance, evaluation systems, quality, curricula, educational and vocational paths, and training environment for all stages of education and training to cope with modern and innovative trends in the fields of STEM education and training (KSA, 2019).

The qualitative professional development program "Khebrat" is one of the leading projects in the Ministry of Education in KSA for teachers' STEM knowledge and skills development that allows teachers to learn about the educational systems of advanced countries in the field of education by immersion in schools during the scholarship period. Teachers, while in the scholarship country are supposed to upskill themselves and sustain their professional development, as well as contribute to the professional development of other teachers through the transfer of impact to reach the goal of the program. Recent research that has focused on teacher professional development in the school context (Popp & Goldman, 2016; Prenger et al., 2019; Zeng & Day, 2019) demonstrate that professional learning communities (PLCs) for teachers have strong capabilities to enable the possibilities of sustainable professional learning through teacher collaboration.

PLCs can contribute to the effectiveness of professional development efforts right from the development of teachers' knowledge, skills and attitudes leading into teacher application of gained knowledge into classroom practice (Darling-Hammond, 2010; Olin & Ingerman, 2016; Rigelman & Ruben, 2012). However, there still exists a gap in literature regarding the suitable methods for sustainable STEM professional development for teachers in KSA. The current study aims to identify the obstacles and challenges for implementing sustainable professional development methods for teachers in KSA, who had participated in a ten-month Australian cross-national STEM professional development program. In addition, the teachers also participated in an immersion in Australian schools that

lasted for 11 months. The current paper reports on a sample consisting of 22 male and female teachers coming from primary and secondary KSA schooling contexts. The participating teachers in the study were a sub-set of the entire cohort of almost 25 teachers who had participated in the Australian STEM immersion professional learning program in 2019-2020.

Why Understand Methods of Teachers' Sustainable STEM Professional Development?

Since the last decade, international research has shown (Darling-Hammond, 2010; Olin & Ingerman, 2016), that when teachers collaborate for professional development, they learn to manage the challenges and complexities of teaching. When teachers collectively work on problems emerging from their own practice, they better meet the needs of all students (Quatroche et al., 2014). Community of practice (CoP) is one method of professional development in which teachers not only create and exchange ideas and documents related to teaching and learning, or routine procedures, but also formulate a set of relationships through social participation (Greene, 2015).

In some cases, online CoP tends to improve teachers' STEM knowledge and skills, where teachers with similar interests or subject specialist areas meet to share their resources, develop STEM pedagogical strategies, solve problems, and support each other to improve their individual as well as student performance (Greene, 2015). In some instances, PLCs of teachers have served as a powerful professional development context, where teachers document and share their practices, thus significantly contributing to more knowledge building and improving instructional practices (Popp & Goldman, 2016). On the flip side, Rigelman and Ruben (2012) suggested that despite widespread acknowledgment of the power of PLCs, the norm in most schools is that teachers continue to work in isolation despite being a part of PLCs. As such there is a need to understand that for effective professional development that can occur in PLCs, and the related pros and cons for teachers to be able to co-construct knowledge with their peers about teaching and learning (Kayi-Aydar & Goering, 2019).

To facilitate professional development of teachers in the online context, the online CoPs has become an important platform in which individuals with similar interests or common goals get together to share their resources, develop working strategies, solve problems, and improve individual as well as organizational performance (Wesely, 2013). These studies have posed the need for PLC models for sustainable teacher knowledge building practices.

Action research (AR) has also become increasingly popular as a method for continuous professional development (Edwards & Burns, 2016). AR is a valuable tool for developing teacher self-efficacy through which it is possible to achieve growth in the effectiveness of teaching, increase self-awareness, improve problem-solving skills, and promote independent learning for teachers.

External partners (outside expert) is another method that can be used to raise the level of professional practices for teachers (Lyna et al., 2016). Lyna et al. (2016) showed when teachers and school leaders participated together under the guidance of a university researcher and with the support of the school leadership group, the collaboration helped introduce teachers to alternative methods for assessing student learning, linking theories with practice in classroom assessment, and acquiring research skills. Ermeling and Yarbo's (2016) study of two secondary school teacher teams explored the potential of collaborative partnerships with outside content experts for infusing new resources and perspectives that move beyond persistent images of classroom instruction. In essence, support from the outside experts broadens the horizons of possibilities teachers can consider during instructional planning. Teaching and learning development in STEM can occur through collaboration between science teachers and researchers. For example, through the integration of 'didactic models' for STEM teaching practice that are aligned with teachers' professional development goals (Olin & Ingerman, 2016). Further, Piqueras and Achiam's (2019) study has documented science museum educators' professional growth during collaboration with researchers and highlighted how educators' STEM knowledge, practices, and beliefs did change. Post-professional development program the educators were keen to take the acquired concepts and ideas forward into the museum's functional resources and integrated into museum practice. To date, methods for teachers' STEM professional development have received limited attention in teacher education literature (Olin & Ingerman, 2016; Rigelman & Ruben, 2012), especially in the context of Gulf Cooperation Council states (El-Deghaidy et al., 2017; Said, 2016). The present research thus seeks to contribute to the literature by investigating 22 KSA teachers' perceptions about methods for implementing sustainable STEM professional

development program in KSA. The study included two research questions:

1. How can sustainable STEM professional development methods be implemented in KSA educational system from the viewpoint of STEM teachers?
2. What are the obstacles in implementing sustainable professional development methods in KSA educational system from the viewpoint of STEM teachers?

Conceptual Framework

Given the effectiveness of the above discussed four methods (PLCs, CoPs, AR, and outside experts) in the professional development of teachers (Ermeling & Yarbo, 2016; Greene, 2015; Kayi-Aydar & Goering, 2019; Piqueras & Achiam, 2019), we have proposed the following conceptual model (**Figure 1**) to examine how PLCs, CoPs, AR and outside expert with the viewpoint of KSA teachers can contribute to our understanding of methods implemented for teachers' sustainable STEM professional development. **Figure 1** contributes to knowledge in conceptualizing a sustainable STEM professional development model for teacher education focusing on collaborative inquiry about teaching and learning. As shown in **Figure 1**, the methods of sustainable professional development are interrelated through shared steps to implement them. Moreover, these methods depend on continuous reflections, teachers' cooperation, and evaluation. In addition, the four professional development methods focus on improving the teaching practices of STEM teachers.

Current State of the Arts of Stem Techniques for Teaching Science, Math, Engineering Incorporating With Technology

The transition of formalizing and integrating STEM education into the curriculum and teachers' practices has recently created a need for teachers' pedagogical and technological understandings. Particularly, in understanding teachers' use of digital technologies into student-centered learning and how STEM can be embedded in their curriculum (Kewalramani, & Havu-nuutinen, 2019; Piqueras, & Achiam, 2019). As KSA vision 2030 promotes the need for 'rethinking pedagogy' for the 21st century learning means teachers identify and integrate the new competencies that today's learners need to develop. Teachers need to explore collaborative practices and opportunities to enable children's STEM and inquiry learning, for example within the pedagogy 2.0 approach. The current state of the arts for STEM techniques for teaching science, math, engineering incorporating with technology is beginning to show how science and mathematics learning advocates inquiry-based learning for teaching, learning and assessment in fostering scientific, mathematics and social studies

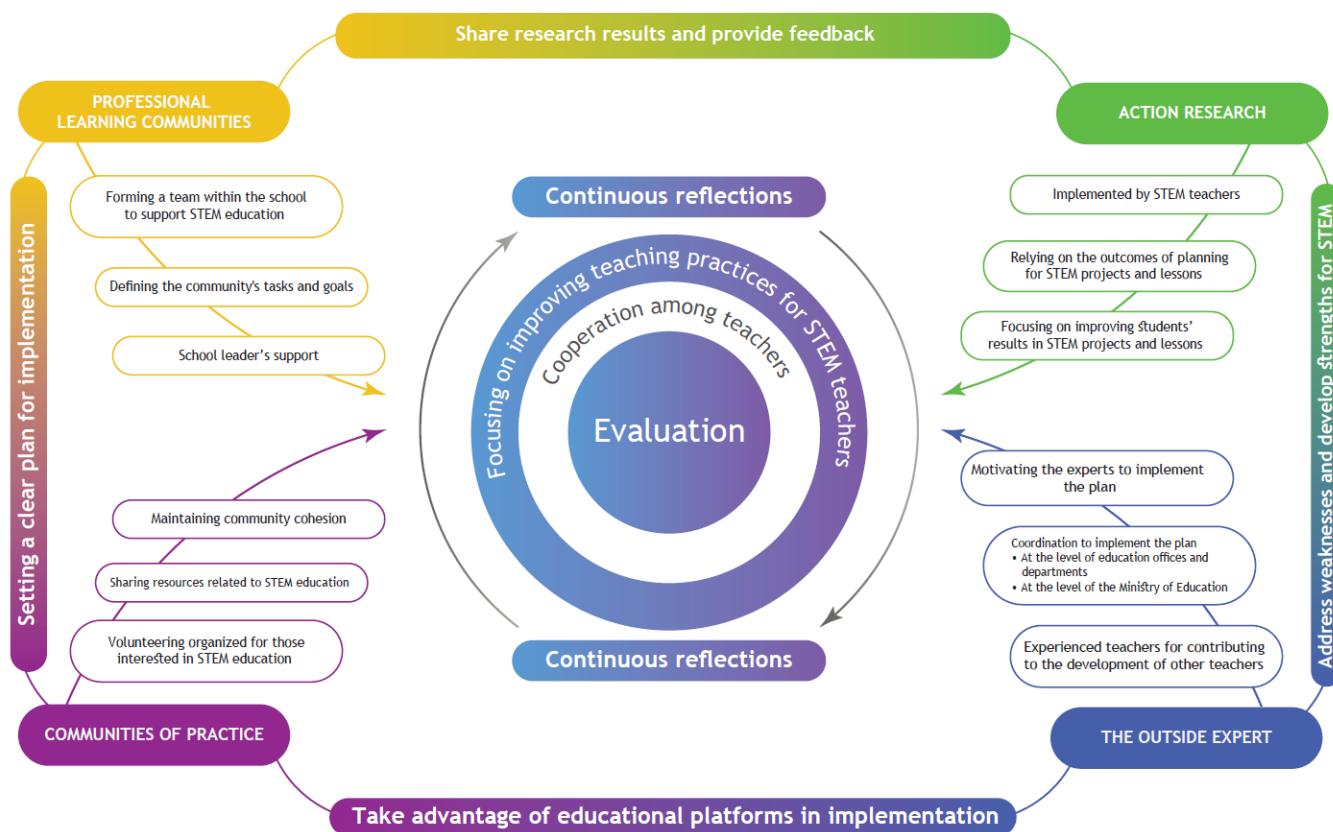


Figure 1. Conceptual framework for implementation of methods for teachers' sustainable STEM professional development (Source: Developed and designed by research authors)

concepts in students (Ailincai & Gabillon, 2018; Milne, 2010; Stylianidou et al., 2018). Yet, there is limited understanding of methods for teachers' sustainable STEM professional development, which the current study aims to fulfill this gap.

As a global need, the current study is of particular importance in light of the recent Organization for Economic and Collaboration Development research report, which highlights how students' higher-order thinking, above and beyond content learning, can be fostered by STEM-supported professional learning models catered to teachers' needs and goals (Kärkkäinen & Vincent-Lancrin, 2013). Calls made for research by El-Deghaidy et al. (2017) that had reported specific contextual issues in their study such as teacher self-efficacy, pedagogical-knowledge, issues related to establishing a collaborative school culture and familiarity to STEM, particularly technology and engineering education among school administrators, students and parents are yet to be realized. Curriculum and policy stakeholders need to provide teachers with sustainable methods and tangible resources, so they feel confident and armed to foster STEM education in KSA classrooms. The study aims to fill this gap drawing upon such unheard research calls (El-Deghaidy et al., 2017; Said, 2016) with respect to examining teachers' perceptions about methods for implementing sustainable STEM professional development program in KSA.

RESEARCH METHODOLOGY

KSA's recent initiatives includes implementation of an economic action plan called the national transformation program 2020. The main aim of the program is to support the vision 2030, which calls for diversity of income and reduce economic reliance on the oil industry. One of the goals is to strengthen the education sector by developing KSA teachers' educational practices in STEM knowledge and skills (KSA, 2019). The vision 2030 states, "we will prepare a modern curriculum focused on rigorous standards in literacy, numeracy, skills and character development" (KSA, 2019, p. 40). Part of the development is to sponsor KSA teachers to live abroad for a year and engage in mentoring programs. The program begins with the nomination of teachers from all regions of KSA according to a specific percentage for each education area. Teachers join the program for one year to build teachers' educational capacities by experiencing worldwide best professional practices to prepare effective leaders for targeted change in various elements of the educational process and to achieve high-quality standards for teaching and learning processes in schools (National Professional Education Development, n. d.). The study's sample is 22 teachers who had participated in a ten-month Australian cross-national STEM professional development program. In addition, the teachers also participated in an immersion in Australian

Table 1. Teacher sample characteristics

Sex		Teaching subject backgrounds			Degree qualification		Teaching experience
Men	Women	Computer science	Sciences	Mathematics	Bachelor	Master	All between 6 & 13 years
15	7	15	4	3	17	5	

Table 2. Interview protocol for teachers

No	Questions
1	What way do you propose to implement the STEM Professional learning community within the school?
2	How can school leadership support the implementation of STEM Professional learning communities?
3	How to motivate teachers to join STEM professional learning communities?
4	What STEM resources can be shared in STEM community of practice?
5	How can we maintain cohesion and cooperation in practice societies for STEM education?
6	How can action research contribute to the development of teacher practices in STEM?
7	How can we motivate the outside experts to spread their experiences?

schools that lasted for 11 months. **Table 1** provides the teacher participant characteristics.

We employed a mixed-method research design, which is a method for collecting, analyzing, and mixing quantitative (open-ended questionnaires) and qualitative data (interviews) to understand a research problem (Abu Allam, 2013). We have chosen the grounded theory approach of the qualitative methodology through the use of a repeated process of data collection and analysis (Creswell & Poth, 2019) to reach clear explanations about how STEM teachers applied sustainable professional development methods. Moreover, descriptive analysis has been used to describe the quantitative data to identify the obstacles that may hinder the application/implementation of sustainable professional development methods from the point of view of STEM teachers.

Data Collection

Because of the COVID-19 pandemic restrictions, the data were collected by in-depth distant interviews using the zoom meeting application. The interviews were conducted with the study sample and analyzed in the mother tongue of the study sample, i.e., Arabic language, after receiving approval to conduct the interview that was signed electronically by the teachers who agreed to participate in the interview. These interviews are guided by the study's research questions (see **Table 2** for the interview protocol). Before any data analysis began, the transcripts were member checked by the third author and three teacher participants to ensure reliability and trustworthiness of the data (Denzin & Lincoln, 2011).

In addition to open-ended questions to gain a deeper understanding of the study sample views on the research problem, we also considered implementing an open-ended questionnaire and invited the participants. The rationale was to capture responses from the teachers who might have not been otherwise able to express them freely in the interviews (Onwuegbuzie & Leech, 2006). Furthermore, triangulation (i.e., seeking convergence and corroboration of findings from different methods

such as interviews and questionnaires is an important step that we considered for the reliability and validity while studying the research problem (Creswell et al., 2003). Due to the nature of the grounded theory approach, the researchers also considered that there was insufficient data obtained from interviews and open-ended questions, so the researchers made a review of short clips previously published in the accounts of scholars of the specific professional development program (experiences 3) in Twitter for 11 persons from the study sample, and also a review of the graduation projects (capstone project) for all study sample members to gain a deeper understanding about their views of the mechanism for sustainable professional development.

To build the quantitative tool (obstacles questionnaire), we followed the exploratory sequential mixed methods, where Creswell and Poth (2019) refers to it as a two-stage mixed method design. In the first phase, researcher collects and analyzes qualitative data. In the next phase of our study, we employed the results of the first phase ensuring a thorough needs analysis to inform the planning for the collection and analysis of quantitative data in the second phase. As for the quantitative data, we developed a questionnaire containing a set of obstacles that were deduced after analyzing the teachers' responses from the interviews that informed about the obstacles teachers faced for implementing each method for STEM professional development (Creswell & Poth, 2019). The obstacles were obtained based on the analysis of the interviews, particularly focusing on the question about the most important obstacles that apply to enabling STEM teaching practices in KSA. The obstacles were not derived from previous studies, but rather from the responses of the teachers. Examples of the obstacles and the difficulties were—the work plan of the PLCs of STEM education, there are no incentives to participate in the communities of practice of STEM education, the large number of teaching load for teachers. It is important to note that to seek reliability and credibility of the data, it was important that the study findings should not be taken for granted but were verified empirically through

qualitative and quantitative methods too. Thus, both the interviews and obstacles questionnaire produced standalone data sets that were also mutually informed by each phase findings.

Teachers were invited in the form of an electronic questionnaire to seek their opinions regarding the importance of these obstacles in influencing the application of sustainable professional development methods. To conduct the research in an ethical manner, the first author invited the participants via emails and sought their informed consent for the interview and questionnaire participation as well as teacher's permission to record the interviews was sought. Two participants did not agree to participate in the interview and hence as per their request we provided the teachers with questions, which were then sent to the first author in writing. While reporting the findings of this study, we have changed the names of the teacher participants with pseudonyms and adopted in the interpretation and discussion of the results. As such, the study ensured to follow the ethical guidelines as approved by the first and the third author's university.

Data Analysis

To reach a profound understanding of qualitative data, the researchers used three coding stages: open, axial, and selective (Creswell & Poth, 2019). Firstly, through open coding, the researchers examined the interviews and open-ended questions to obtain prominent categories of coding from the provided information. By using the constant comparative approach, we tried to satisfy the categories by searching for examples that indicate such categories and comparing those categories with each other. When we felt that the information presented in the interviews and open-ended questions is not sufficient due to the expertise of researchers in the educational field as the data presented by the study sample in the interviews and open-ended questions do not set out an actual plan to implement the methods of sustainable professional development, therefore, we returned to other sources, i.e. video clips of the study sample previously recorded and published on Twitter, in addition to analyzing the graduation projects (capstone projects) of STEM teachers to reach a deeper understanding about the way of implementing sustainable professional development methods. Thus, we got 476 codes in the open analysis stage. Second, the axial approach in which all the study tools were reviewed to know the overlapping conditions among the categories that constitute professional development methods and a way to benefit from them in building a model and clear explanations about the proposed theory. At this stage, similar and overlapping symbols were collected in two phases (Figure 2).

The researchers obtained 48 symbols in the first stage and 18 symbols in the second stage, which represent the

basic categories for analyzing qualitative data. Lastly, through selective coding, we generated proposals for the phrases linking the categories in the coding model to build clear explanations linking to study's conceptual framework (Figure 1) on how STEM teachers implement sustainable professional development methods.

To analyze the questionnaire quantitative data, we used descriptive statistics (means, iterations, and standard deviations [SDs]) to identify the obstacles that may hinder the implementation of STEM teachers for sustainable professional development. The study tools (interviews, open-ended questions, video clips, and graduation projects) provided a clear view of the sustainable STEM professional development plan for teachers in KSA. The results are presented according to the study's questions: Firstly, we present the interview findings for the study's first research question.

Reliability and Credibility of Data Analysis

Researchers have sought to achieve the reliability of qualitative data through the realization of credibility criteria through the following: Arbitration of the interview tool by specialists in curricula and teaching methods, in addition to those interested in STEM education. The arbitrators suggested adding a brief explanation of the basic concepts in the interview (PLCs, communities of practice, procedural research, external experts), and the arbitrators also suggested adding sub-questions that help researchers gain an in-depth understanding of responses such as:

what plan do you propose to implement PLCs, how to motivate teachers to join PLCs to teach STEM, and how we can maintain the coherence and collaboration of communities of practice for STEM education?

To ensure the credibility of the data, the researchers followed several methods that increase the credibility of qualitative research, such as member checking that involved the analysis of video clips of the study sample already recorded. Thus, seeking feedback from whom the research has been done so they could indicate their agreement or disagreement with the way the authors represented them.

Re-examining the findings through the method of member checking allowed for more accuracy and member validation (Cho & Trent, 2006; Denzin & Lincoln, 2011). Feedback on the capstone projects' analysis of STEM teachers to reach a deeper understanding on how to implement sustainable professional development methods was also sought to reach a high degree of data reliability.

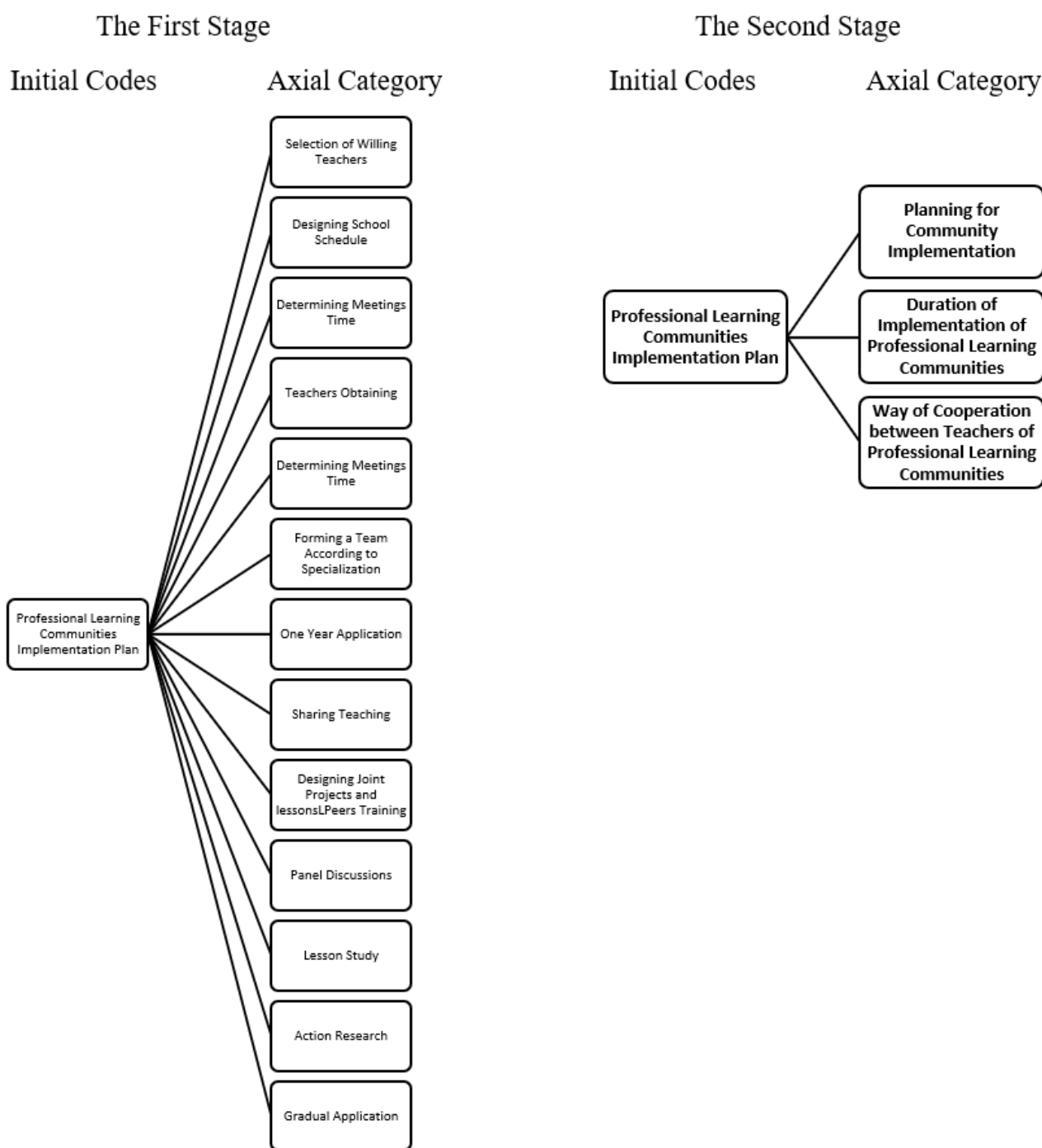


Figure 2. Sample for axial coding (Source: Developed and designed by research authors)

FINDINGS

Following is a detailed presentation of the analysis of the findings in line with the study’s conceptual framework: PLCs, communities of practice, AR, and outside experts.

Professional Learning Communities

This section reports on the study’s first research question which entitled “How can sustainable STEM professional development methods be implemented in KSA educational system from the viewpoint of STEM teachers?”

To implement PLCs, STEM teachers see that it can be achieved by setting a clear plan in the school to build a professional learning community, especially for formal STEM education in the school. The majority of KSA teachers articulated that the plan should be implemented gradually. Hatim, a male teacher expressed,

“The application process should be gradual as the teacher conducts a comprehensive study for the program in terms of knowing the pros and cons.”

The teacher communities’ application of the plan should be a study for a complete year. Teacher 6 says,

"We continue for a year and evaluate the community's work and present the results to the rest of teachers that we may get a better turnout and joining from them."

The school day is really crowded in Saudi schools due to the teacher's big teaching load, assigning him/her additional work, and the unavailability of free time for the meetings of PLCs. Therefore, KSA teachers participating in the study suggested that it is important to have meeting options, including planning meetings at the beginning of the year, meeting in the weekly activity sessions, and distant meetings. Consequently, teachers' practices in STEM education will evolve through continuous collaborative work among teachers in the professional learning community through panel discussions, workshops, and application of lesson study together with the evaluation of how teachers were traversing the newly acquired STEM knowledge. The mechanism of cooperation among teachers in STEM PLCs is evident by identifying common lessons in each discipline. One male teacher Mohammed articulated,

"Teachers can participate with each other in planning some lessons and conducting a continuous evaluation to ensure a clear understanding of STEM education."

STEM activities should be "based on project-based learning and should contain real problems."

The teacher participants also envisaged the importance of providing incentives for continuing the work of PLCs. Moaiad pointed out that

"the school leader must take into account those interested in STEM education by waiving in-wait periods, supervision at break time (breakfast break), and health supervision."

The importance of school leader's support becomes prominent through the successful organization of the action plan of PLCs of STEM teachers by "providing time and place for meetings and providing convenience and flexibility to enable them to implement anything new." Rahaf added that one of the things that teachers need to implement PLCs especially for STEM education is to prepare the place for the attendance and the implementation of professional development courses because not all the activities of the professional learning community are done distantly. The plan may include direct meetings, direct courses, and simple materials such as a whiteboard and projector, which are sufficient. But if the idea of PLCs is new to the school, STEM teachers may find it difficult to implement it and the idea is opposed by the school leader. Therefore, Samar, a female teacher proposes to gain the leader's trust first by

"holding a meeting with the school leader and giving him/her a general idea through references

and studies. If there is an acceptance of the idea by the leader, that will facilitate the process."

However, there was also a pessimistic opinion in the teachers' perceptions of how PLCs may work for their professional development. Saad perceived that the attempt of one teacher to apply PLCs is

"difficult and almost impossible and requires the intervention of education offices and the Ministry of Education in adopting such initiatives."

The teachers perceived that participating in communities of practice was seen a voluntary practice in the midst of their busy school day and teaching schedules. Samar suggested that

"the volunteering culture must be spread and expanded among teachers".

To implement the communities of practice, the teachers should be encouraged to see CoP as a process of preparation of STEM teachers to adopt the initiative at the level of entire schools in KSA. Accordingly, Saad stressed that

"the initiative has to be at the level of all schools in KSA rather than at the level of education departments and it must include a partnership with educational institutions, where STEM clubs are outside of working hours."

The role of education departments is evident in

"motivating teachers to participate in these communities by adopting and supporting them" (Kamal).

In order to achieve effective communication between KSA teachers to indulge in professional development, an electronic platform should be created that brings together the teachers who are interested in STEM education. The education departments must take responsibility for the arrangement for that. Therefore, Hams, a female teacher noted that

"if a STEM official in the administration adopts such an initiative; and we are allowed to communicate and participate via any electronic platform so that we can hold a meeting whether a direct meeting or an online meeting."

It is also possible to "create groups on social media, such as Telegram or WhatsApp, through which experiences in the field of STEM can be exchanged" to achieve the goals of the communities of practice. It was clear from these suggestions that KSA teachers were optimistic about developing a culture of CoPs and endeavored to keep in touch via online media platforms for sharing STEM ideas and practices.

There were various sources through which the benefit of establishing STEM education communities can be achieved; but “the most important source is teachers’ sharing of their personal experiences in STEM education with their colleagues.” Thus, the teacher becomes a source for their colleagues “so that any teacher who implements the STEM program and succeeds in doing so must share his ideas with other colleagues.” Moreover, to achieve community cohesion (continuous interaction and cooperation), “there must be a constant renewal in terms of method and ideas so that things do not become a routine that causes teachers to lose their enthusiasm.” The gist from teachers’ perceptions clearly meant that having a moral incentive played an important role in achieving the cohesion of communities of practice. Firas, a male teacher mentioned,

“For example, by announcing the best practice community groups based on certain criteria and providing incentives such as bringing forward their summer vacation. As human nature is, unless we are motivated, we will not continue to work.”

Action Research

The participating teachers believed that AR contributes to the development of the teacher and students. Half the teachers indicated in their interviews that the teaching practices of teachers can be improved through AR. Ahad, a female teacher, for instance, indicates that AR

“helps improve the practices of teachers whether those who are experienced or fresh. It gives every teacher the opportunity to improve his/her practices that will improve the quality of teaching and learning.”

Wafa, a female teacher, perceived that

“through procedural research, the scientific material can be assessed, teaching can be planned based on the research findings, and knowing students’ failure aspects; accordingly, I will draw up a plan for how to strengthen these aspects.”

Thus, AR is considered the best field source through which the STEM teacher can evaluate the actual reality and build his/her plans upon it. This was confirmed by Fahd who says,

“Research is the source through which the secrets of many practices can be obtained. That is why I value research and believe in getting the information from its source.”

Saad believed that

“AR is the basis of STEM because through which the real evaluation of STEM projects is carried out. For example, the evaluation of interaction and cooperation in an impressionistic manner is not an indication; rather through AR, a real evaluation of the projects can take place.”

Due to the fact that AR and PLCs are applied directly in schools, the teachers considered the importance of sharing the findings of AR carried out by STEM teachers during and after applying the projects and lessons with PLCs in school. This can be done through “transferring the experience with its full details and sharing it with other colleagues by clarifying how the experiment was carried out starting from the problems until reaching the findings” or “by presenting them in the meetings in the form of a summary through a presentation that contains graphics and percentages that explain the teacher’s experiments and the results that he reached with the students.”

Outside Experts

The outside experts are specialized STEM teachers who were trained in the ‘Khebrat’ program. They have sufficient experience to contribute to the professional development of other teachers in schools other than their schools. By asking teachers how they envisaged to apply the idea, of outside experts as a sustainable professional development method for other teacher, it was clear from the responses of teachers that this method can be applied in two directions. Firstly, at the level of education offices and departments; and secondly, at the level of KSA Ministry of Education. At the level of education offices and departments, it can be implemented by the teacher themselves. Hatim suggested,

“the teacher begins applying the STEM program in his school; studies it from all aspects, i.e., in terms of pros and cons, how to improve them, as well as their development; and in the end begins transferring and generalizing them at the level of other schools.”

Another teacher expressed that it was also possible to create model schools that fully implement the STEM program and other teachers visit them. Saad reinforcingly mentioned,

“when we have a school that applies STEM program realistically, the teacher can see how the STEM program is actually implemented.”

Thus, “the school has a group of experts. It becomes an expert house. Teachers at other schools, especially those newly appointed, can be sent to such [expert] schools to gain experience. So that they obtain experience in a practical way in the field and acquire STEM knowledge through practice.”

The educational supervisor has a great role in coordinating teachers' visits to schools "because the teacher does not have the ability to visit other schools or even know about them. So, it is possible for the teacher to cooperate with specialized supervisors in the education office after giving them a review of his experience and convincing them. Then, he can first start with documenting his experience, assessing its impact on his school, and finally evaluating it". The visits should be scheduled weekly for each expert. Talal states that

"we, the returnees from the BLCSEI program, are supposed to be a source for others to carry out this revolution and to transfer the experiences because STEM program is considered new. This can be implemented through school tours so I can visit schools by designating some days per week for this purpose. Thus, within 16 weeks, 16 schools can be visited, and consequently spreading the STEM culture."

The experts can also spread STEM culture at the level of KSA through "conferences. Such conferences can be dedicated to them so that the worksheets are presented by the teachers of the (Khebrat) program themselves as visitors. They should be introduced as experts who have gained experiences from developed countries and have come to present the scientific material they gained". Since STEM is a new culture in Saudi schools, so Talal thinks that

"we can start from scratch, and we can be leaders in the field of STEM education. STEM teachers can be assembled from every department and have a one-day meeting. The meeting can be online provided that they meet under the experts' umbrella and task and not just to provide lessons."

To realize the method of outside experts as a method of sustainable professional development, STEM teachers believed that this corresponded to the motivation of experts by "giving freedom to teachers to implement what they want and facilitate the potentials for them because STEM has a wide application, and many people, especially officials, think that it is difficult to implement, and this will consequently hinder the implementation of projects". Moreover, "the presence of a moral incentive in the work environment from the school leader, teachers and the office, and the support from the direct supervisor to share ideas with other teachers" as well as "the certificates of appreciation" and "the honoring the participants in the program" motivate the expert to spread the STEM culture.

The following section reports findings from the questionnaire data that answers the study' second question: What are the obstacles in implementing

sustainable professional development methods in KSA educational system from the viewpoint of STEM teachers?

Obstacles to Implementing Sustainable Professional Development Methods

To identify the obstacles, the teachers were asked during the interviews a question about the obstacles they believed might hinder the implementation of the sustainable professional development methods. The results showed that STEM teachers demonstrated that there were 66 obstacles that may hinder or slow the teachers' implementation of sustainable STEM professional development methods. These obstacles are as follows: the first axis PLCs has 18 obstacles, the second axis: CoP (17), the third axis: AR (17), the fourth axis: outside experts (14). Then, the researchers saw the necessity of obtaining more data about these obstacles, hence a refined quantitative tool (questionnaire) was built from the qualitative data of the interview tool, the most important obstacles were identified for each of the sustainable professional development methods after excluding the obstacles that were mentioned individually and were not repeated. The questionnaire consisted of 28 obstacles, as follows: PLCs had nine obstacles, CoP had eight, AR had six, outside experts had five, as shown in **Table 3**.

To explain the results of **Table 3**, we focus on the obstacles that the teachers considered as important and which obtained high arithmetic mean, in addition to the obstacles that were less important from the point of view of the study sample, and which have obtained low arithmetic mean. A review of the results of **Table 3** showed that the most important obstacles of the first axis: the implementation of PLCs. There was no arrangement in the school schedule for the meetings of the professional learning community members of STEM education from the point of view of STEM teachers. Therefore, reported with an arithmetic mean of 4.26. The effect of the lack of adding time for the meetings of the PLCs in the school schedule to implement PLCs was supported by the answer of Firas to a question about the plan the teacher proposes to start implementing PLCs for STEM teachers. He pointed out the importance of assisting the school principal in designing the schedule of teachers so that he arranges periods in the school schedule for the meetings; consequently, the team can work and implement the STEM program. The second obstacle was in accordance with the teachers' beliefs that the completion of the course explanation was more important than the implementation of PLCs of STEM education with an arithmetic mean of 4.04. The teachers agreed that school subjects in KSA are academic and content-based and require the teacher to spend longer periods of time to tick off the curriculum, which makes the teachers to refrain from applying any other professional development activities such as the PLCs.

Table 3. Obstacles to implementing sustainable professional development from the viewpoint of STEM teachers

The first axis: The obstacles of professional learning communities				
No	Statement	Mean	SD	Order
1	The secondment of the teacher to other schools, which affects the work plan of the professional learning communities of STEM education.	3.82	1.07	4
2	Teachers are not cooperative in implementing the professional learning communities of STEM education.	3.47	1.08	5
3	School leaders are not cooperative in implementing the professional learning communities of STEM education.	3.30	0.97	6
4	The scarcity of teachers of scientific majors in some schools.	2.86	1.42	9
5	The nature of professional learning communities is unclear in the educational field.	3.86	1.01	3
6	Teachers are not able to share their opinions in the professional learning communities of STEM education.	3.21	1.12	8
7	There is no acceptability of change on the part of teachers.	3.26	1.09	7
8	There is no arrangement in the school schedule for the meetings of professional learning community members of STEM education.	4.26	0.81	1
9	Teachers believe that completing the course explanation is more important than implementing professional learning communities of STEM education.	4.04	1.06	2
The second axis: The obstacles to communities of practice				
1	Communities of practice are not officially recognized.	4.04	0.92	3
2	There are no incentives to participate in the communities of practice of STEM education.	4.21	0.95	1
3	There is not enough time to participate in the communities of practice of STEM education.	3.52	0.84	6
4	There is no clear plan for communities of practice of STEM education.	4.17	0.65	2
5	Teachers are not convinced of the importance of communities of practice of STEM education.	3.82	1.02	4
6	School leaders are not convinced of the importance of communities of practice of STEM education.	3.56	1.27	5
7	The ministry officials are not convinced of the importance of communities of practice of STEM education.	2.95	1.10	8
8	There is no encouragement from the leaders to participate in the communities of practice of STEM education.	3.39	1.03	7
The third axis: The obstacles to action research				
1	The large number of teaching load for teachers.	4.39	0.72	1
2	Assigning additional tasks other than teaching to STEM teachers.	4.34	0.64	2
3	STEM teachers do not have sufficient knowledge of how to conduct action research.	3.65	1.22	4
4	There are no sufficient resources available for carrying out action research.	3.13	1.28	6
5	The long duration of carrying out action research.	3.30	0.92	5
6	The density of the content of the educational courses.	3.95	0.92	3
The fourth axis: The obstacles of outside experts				
1	The large number of teaching load for STEM education experts.	4.34	0.57	2
2	Assigning additional tasks other than teaching to STEM education experts.	4.26	0.54	3
3	School leaders believe that the participation of the STEM education experts in the professional development of teachers at other schools will hinder the workflow of the school schedule.	4.08	0.90	4
4	STEM education experts are not encouraged to contribute to the professional development of teachers in other schools.	4.08	0.90	5
5	Lack of coordination among schools to benefit from STEM education experts.	4.56	0.66	1

The least important obstacle from the teachers' viewpoint was the scarcity of teachers of scientific majors in some schools with an arithmetic mean of 4.04. The interpretation of this is that STEM is a wide field, and it can be applied by all teachers in all disciplines. The application of STEM is not limited to scientific disciplines (science, mathematics, and computer).

In the second axis of **Table 3**, the quantitative data of the questionnaire showed that the first obstacle to the implementation of communities of practice is that there were no incentives for teachers to participate in the communities of practice for STEM education with an arithmetic mean of 4.21. Moaiad believes that

"it is not a condition that the incentives be material. There are some psychological incentives that motivate the teacher such as the letters of thanks."

In the second place comes the statement that there is no clear plan for communities of practice for STEM education with an arithmetic mean of 4.17. The plan is supposed to be clear "and not be according to random decisions of teachers in the communities, and with complete conviction that STEM results do not appear in short-term periods". The statement that the officials in the ministry are not convinced of the importance of the

communities of practice of STEM education comes in the last place with an arithmetic mean of 2.95. The researchers endorse that the statement “officials are not convinced of the importance of STEM” is considered the least of the obstacles due to the presence of great support from the Ministry of Education to establish PLCs for teachers. The ministry has conducted several courses in this aspect and issued a guide explaining the mechanism for building PLCs.

As for the obstacles to implementing the third axis: AR, the large number of teaching load for teachers comes in the first place and assigning additional tasks other than teaching to STEM teachers in the second place. It is apparent that the teachers were busy with teaching and non-teaching tasks including administrative work; thus, the teachers did not have time to join PLCs. The statement that there are insufficient resources available for the implementation of AR comes in the last place with an arithmetic mean of 3.13. This finding can be attributed to the interview data that technology resources available for the teachers could be facilitated to provide teachers an opportunity to access research or listen to lectures on AR through the Internet.

Finally, the obstacles of the fourth axis: the outside experts, in the first place comes the lack of coordination among schools to benefit from STEM education experts. Wael stressed the importance of organizing expert visits to different schools. His role is to direct and guide the work of colleagues in these schools to assure that these teachers adhere to the project. The role of the expert is to follow-up and supervise the level of progress of this project and how to accomplish it. It was also noted that the large number of teaching load for STEM education experts was the most important challenge that the STEM teachers faced when implementing sustainable professional development methods as it had been repeated as an obstacle to AR and outside experts methods. Among the obstacles of implementing outside experts, the statement that STEM education experts are not encouraged to contribute to the professional development of teachers in other schools comes in the last place.

DISCUSSION AND CONCLUSIONS

This study responds to the call for the need to develop professional development practices for leaders, supervisors, teachers, and student guidance within the framework of international standards, particularly in line with KSA’s vision 2030. The current study is unique in identifying the obstacles and challenges for implementing sustainable professional development methods for teachers in KSA, who had participated in a ten-months cross-national Australian STEM professional development program. Similar to past research (El-Deghaidy et al., 2017; Said, 2016), the results of our study showed that the most prominent obstacles to the

implementation of the sustainable professional development methods by STEM teachers in the Saudi educational system were: there was no coordination in the school meetings schedule for the members of the professional learning STEM education community, there was no clear plan for communities of practice of STEM education, teachers’ overload teaching duties, coupled with the lack of coordination between neighboring schools to benefit from STEM outside experts. These results demonstrate teachers’ apprehension in implementing the methods (as outlined in the conceptual framework-**Figure 1**). The nuanced findings of this study demonstrate that the teachers perceived the PLCs were seen as a top-down approach and wished that STEM professional learning should be coming from the leadership personnel. This contrasts with Rigelman and Ruben (2012) study where teachers wanted to continue working in isolation despite receiving some level of professional development supports. Whereas, in the current study, the teachers were keen to collaborate to form a CoP, but the hindrance was the lack of leadership support that disempowered the teachers motivation to collaborate in PLCs due to the obstacles they faced. Nevertheless, the teachers still saw the importance of giving them freedom to create and plan the PLCs. The teachers were considering how STEM education could be implemented within the constraints of KSA curriculum and as a rigorous approach that should be mandated by the Ministry of Education personnel. Further, the demands on daily teaching practices were raising a number of tensions for them in terms of the need for flexible times that could be spent on PLCs, CoPs, or AR initiatives.

While the results in this paper only represent teacher perceptions and their own readiness to participate in STEM professional development methods, the data does provide evidence that teachers are beginning to broaden their thinking about what matters for them as motivation to participate in STEM education. Further research should involve further large-scale survey data and the analysis should continue to explore changes in KSA teachers’ thinking about STEM education and how they would motivate themselves despite the systemic barriers and obstacles teachers face (Darling-Hammond, 2010; Olin & Ingerman, 2016; Rigelman & Ruben, 2012). While research has shown us since decades that PLCs do impact on teachers’ considerations and motivations for up taking professional development, it is now time to create sustainable programs and allow teachers to take the time and efforts in the midst of their busy schedules to partake in STEM education learning and practices (Darling-Hammond, 2010; El-Deghaidy et al., 2017; Piqueras & Achiam, 2019). This study’s conceptual framework provides evidence for the challenges, tensions and obstacles that should be further looked at while considering developing STEM professional development programs for teachers (Greene, 2015; Kayi-

Aydar & Goering, 2019). In answering the study's principal research focus being identifying the obstacles for the implementation of sustainable understandings of STEM education rather than teachers' individual and personal goals for STEM professional learning.

Recommendations

The current study highlights the need to identify key program activities or experiences that teachers holistically feel best to help them to challenge or improve their motivation for STEM practices. We recommend further research studies to firstly understand the benefits for incorporating STEM in classroom teaching practice and student achievement (Stylianidou et al., 2018), and secondly teachers to uptake STEM professional development methods (see **Figure 1**). We need to make a shift in teachers' confidence, motivation, and pivoting mindset, despite the enormous demands of teaching that teachers currently face in a crowded curriculum. Through professional development methods teacher need immense support from the school leadership personnel, both at the local and national level (Piqueras & Achiam, 2019). Policy makers and the Ministry of education stakeholders should endeavor to engage teachers in professional development programs such as research-practitioner collaboration programs (outside experts). Although, the present findings are based on a relatively small data set and the analysis examined only four key methods for sustainable STEM professional development, we recommend further studies to examine how the topic of teacher obstacles, motivations and personal goals are related to the emergence of knowledge building discourse for teacher STEM education professional development and related frameworks.

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