JPII 10 (3) (2021) 357-367

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

STEM TEACHERS' PROFESSIONAL DEVELOPMENT THROUGH SCIENTIST-TEACHER-STUDENTS PARTNERSHIP (STSP)

R. M. Saat[1], H. M. Fadzil*[2], D. S. H. Adli[3], K. Awang[4]

[1,2]Faculty of Education, University of Malaya, Kuala Lumpur, Malaysia
[3,4]Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia

DOI: 10.15294/jpii.v10i3.27845

Accepted: December 18th 2020. Approved: September 28th 2021. Published: September 30th 2021

ABSTRACT

Teachers are one of the most fundamental sources for the latest scientific information. However, many feel that teachers lack sufficient knowledge and skills to play this role, particularly in STEM, as STEM is related to more than one discipline. This study explores Scientist-Teacher-Students' Partnership (STSP) as a professional development programme to enhance teachers' understanding and conceptualization of the cutting-edge STEM knowledge and real-life applications of the STEM concepts. This study employed a qualitative research methodology, and it involved nine science teachers from four secondary schools and ten scientists from a university situated in Kuala Lumpur, Malaysia. Data were collected through observations made during activities and interviews. The collected data were analyzed using constant comparative data analysis techniques. Overall, the findings suggested that the tripartite collaboration brings educational benefits to all groups. From the perspective of teachers' professional development, it was found that the partnership: (i) enhanced the teachers' understanding of cutting-edge STEM knowledge; (ii) elevated their confidence and enthusiasm in STEM; and (iii) provide opportunities for information exchange and support through school-university networking. This study had promoted a more significant articulation of STSP as a mechanism for professional development in STEM education.

Keywords: STEM; partnership; professional development

INTRODUCTION

The digital revolution has transformed the way students learn, access information, and communicate with each other. It is our professional obligation as educators to ensure that we are providing students with the skills they need to be successful in the future (Tong & Razniak, 2016). Thus, there is a need to transform education, particularly in the field of STEM education regularly. Change in the education setting is essential to narrow the gap between the conventional educational system and the emerging demands of the information age. In addition, no matter how good pre-service training is for teachers, it is inevitable that the teachers might face new challenges throughout their careers (Rutkowski et al., 2013). Given the goal of becoming a knowledge-based driven economy, enhancing the quality of teachers' education is a priority in most nations, including Malaysia. Most nations would like to have the world's standard education system with a high-quality teacher workforce. To achieve this goal, it is important to have continuous professional development by upgrading in-service courses offered to teachers. These are essential components in improving teaching quality, and it is mandatory for teachers who undergo curriculum change or involve in new curriculum initiatives. In addition, staff development programmes should cover a wide range of areas based on the teachers' needs, particularly keeping abreast with

***Correspondence Address**
E-mail: hidayahfadzil@um.edu.my

the current demands of the 21st-century skills and Industrial Revolution 4.0. Attendance in such professional development programmes remains fairly low, as suggested by previous studies (e.g., Reston et al., 2014).

Despite the lack of professional development programs, training sessions and workshops for in-service science teachers, they are usually too short and too rare to encourage a change in their classroom practices. The low numbers in attendance and the teacher's involvement in programmes that are not addressing their needs also contribute to the issues in science teachers' professional development. Previous studies (e.g., Siew et al., 2015; Ramli & Talib, 2017) reported that most science teachers are still struggling to make connections across the STEM disciplines. The lack of understanding of STEM may lead to a sense of incompetence among science teachers, as suggested by Mahmud et al. (2018). In Malaysia, STEM is not taught as a subject in school. Thus, there is no specific teacher trained in STEM education.

As mentioned earlier, no matter how good pre-service training for teachers is, it cannot be expected that teachers will be prepared for all the challenges they will face throughout their careers (Aldahmash et al., 2019). Education systems should therefore seek to provide science teachers with opportunities for ongoing professional development to maintain a high standard of teaching practice. Hence, scientist-teacher-student partnership (STSP) programme might be one of the beneficial avenues to enhance teachers' professional development, particularly to cater to the needs in STEM education.

The International Teaching and Learning Survey (TALIS) adopts a broad definition of professional development among teachers (OECD, 2009). Professional development can be defined as activities that develop and enhance the skills, knowledge, expertise, and other characteristics of the individual as a teacher (Rutkowski et al., 2013). Professional development can be provided in many ways in this context, from the formal to the informal. It can be made available by external expertise in the form of training courses, workshops or formal qualification programmes (e.g., a degree or master's programme), education conferences, or seminars. It is through workshops and conferences that teachers are able to share their research findings and address educational concerns, through partnerships between schools or teachers around schools (e.g. observational visits to other schools or teacher networks) or within schools where teachers work. Development can also be achieved through coaching, mentoring, collaborative planning and teaching and the sharing of best practices among science teachers (Rutkowski et al., 2013). In the case of Malaysia, the Ministry of Education has set up in-service training programmes, which often serve as the platform to train teachers for any curriculum reforms. Professional development training is also carried out using a cascade model, which includes the coaching of selected teachers by master trainers. The appointed teachers are then expected to conduct training at either state and/or district level with other teachers (Mahmud et al., 2018). The training can also involve in-service courses and training workshops.

Teachers are expected to gain and improve their teaching skills in the teaching profession, implement effective teaching techniques, and become apprised of development in science content (Aldahmash et al., 2019). There is an important need for the teacher to provide students with characteristics of STEM education (Gallant, 2010; Fadzil et al., 2019; Permanasari et al., 2021). Gallant (2010) describes STEM-educated students as problem solvers, logical thinkers, technologically literate, and able to relate their own culture to the learning. STEM education should provide students with STEM literacy as a priority and need to be culturally relevant to all students. Thus, in the STEM classroom, science teacher needs to foster inquiry and creativity and encourages assessment practices that are both formative and performance-based. Studies on science teacher professional development (e.g., Aldahmash et al., 2019) discovered that professional development programmes need to be suitable to help teachers in successfully implementing effective teaching methods and strategies in the classrooms. Relevant characteristics of the professional development programme should include engaging science teachers in deep science content and process knowledge with multiple practical opportunities, the expectation that teachers demonstrate expertise in a concrete and evaluable manner, and the opportunity to promote multifaceted and inquiry-based experiences. Thus, comprehensive professional development programs need to be designed, including the use of effective approaches to achieve the ultimate goal of professionalism of teachers (Schaffhauser, 2016; Aldahmash et al., 2019; Barr & Askell-Williams, 2020). Schaffhauser (2016) defines teacher professionalism as covering three domains. The first domain is a knowledge base that includes the knowledge needed for teaching, including formal pre-service education, support for in-service professional learning and research by practitioners. The second domain is autonomy or the decision-making skills of the teachers related to their jobs, such as choices in the curriculum, learning materials, and course content. The third domain is peer networks to provide opportunities for information exchange and support. These domains will be further discussed in the finding and discussion section of this paper.

Dong et al. (2019) found that approximately half of the teachers in his sample are not yet ready for STEM education, and that the teachers have strong concerns about the integration of STEM education in Hong Kong schools. Moreover, training sessions and seminars for in-service science teachers are typically too short and too rare to promote a shift in classroom practices for teachers (Aldahmash et al., 2019). Generally, STEM teachers are particularly poorly prepared. Teacher related issues, such as teachers' lack of STEM content knowledge, and lack of effective STEM teacher professional development (Dong et al., 2019; Geng et al., 2019). In general, STEM teachers are particularly poorly prepared. Teacher-related concerns such as the lack of STEM content knowledge and the lack of efficient professional development programme for STEM teachers make it a challenging task to develop a strong STEM teacher workforce (Sun et al., 2019). Many in-service teacher studies have shown that teachers' involvement in STEM teaching can be improved once they become increasingly confident in their teaching design and teaching skills and get enough support from peers. Many in-service teacher studies have shown that teachers' involvement in STEM teaching can be improved once they become increasingly confident in their teaching design and teaching skills, and if they can get enough support from peers (Geng et al., 2019). Therefore, it is necessary to provide teachers with substantial professional development, pedagogical support, and curricular resources to improve STEM education in practice.

Previous studies demonstrated that effective professional development programmes might improve science classroom practices and eventually, student learning (Aldahmash et al., 2019). However, there is still a growing debate on what professional development can be provided to our in-service teachers in Malaysia. The concept and idea of STEM education are still new in our local context. Studies conducted in Malaysia have found that a majority of science teachers are still struggling to understand STEM concepts and making connections across the STEM disciplines (Mahmud et al., 2018; Fadzil et al., 2019) and this might potentially lead to the feeling of incompetency among science teachers (Ramli & Talib, 2017).

In order to enhance teachers' confidence in integrating STEM in the teaching and learning of science subjects, relevant in-service training needs to be provided. Therefore, the science teacher education program should be properly designed to respond to the changing responsibilities of science teachers. In order to achieve this goal, it is suggested that the science teacher education programme should provide sufficient exposure to prospective science teachers in a variety of practical STEM education approaches. The current study is located within the field of professional development for STEM teachers, which poses the question: what knowledge and skills do teachers need to have in teaching STEM subjects?

A traditional teacher views factual knowledge as the most fundamental student outcome, achievable through repeated drill and practice (Mansour, 2015). This may be due to the fact that after leaving their pre-service training, teachers have limited opportunities to keep abreast of the ever-changing STEM-related fields. This field is a fast-moving field, with new discoveries in scientific knowledge, and new practical techniques. However, teachers tend to feel more comfortable to just rely on textbooks, lectures, and demonstration labs rather than facilitating STEM experiences. Teachers give priority to the transmission of facts than to enable students to carry out their own scientific investigations. Perhaps, the most challenging obstacle is teachers' reluctance to feel out of control about what is going on in their classroom, as they need to conduct innovative experiments for the STEM programme. Teachers tend to be more comfortable with the traditional cookbook approach in which the outcome of laboratory experiences is predetermined (Fadzil et al., 2019). Engaging students in Scientist-Teacher-Student Partnership (STSP) requires them to have appropriate pedagogical tools, confidence, commitment and optimism about achieving the goals of reform-based science education standards. Hence, Schaffhauser's (2016) third domain focuses on networking and partnership as an essential domain in professional development. Through the STSP approach, teachers may gain higher confidence and increase their enthusiasm for teaching the subjects and are able to guide students in choosing a STEM-related career.

For the purpose of this paper, professional development focuses on the knowledge, skills and attitudes required for science teachers that are directed toward students' learning of STEM-related subjects at a higher level of education. STEM educators need to constantly update their knowledge and skills, just as any professionals in other fields. Reston et al. (2014) found that teachers' professional development was the least pursued research area conducted, particularly by Malaysian researchers. Thus, there are critical needs for innovative research in professional development for preparing STEM teachers.

One of the initiatives is through Scientist-Teacher-Student Partnership (STSP) programme. The collaboration provides a variety of professional development opportunities where science teachers learn new knowledge and skills in STEM from scientists. This knowledge can then be implemented in the classroom. 'Partnership' in the context of this study refers to a symbiosis where each entity significantly gains through collaborations in sharing research, teaching and service. Mansour (2015) described that the STP programme provides further understanding of the practice of science or STEM-related subjects in the real-world context. Thus, such a partnership has been used as a teacher professional development initiative aimed primarily at enhancing teachers' STEM knowledge and skills, as mentioned by previous researchers (e.g., Falloon, 2013; Mansour, 2015; Roehrig et al., 2021). This study is part of a more extensive study where the goal of this study is to investigate the students', teachers', and scientists' perceptions and experiences of the STSP programme. However, this paper focused only on the aspect of the professional development programme within the context of STSP. In particular, the researchers focused on the following research question: How can the STSP programme enhance teachers' professional development, particularly in the teaching and learning of STEM-related subjects?

METHODS

This study employed a qualitative research methodology to explore teachers' perspectives of the STSP programme in the context of teachers' professional development. The researchers attempt to identify how these STSP programmes can enhance teachers' understanding and conceptualization of the cutting-edge of STEM knowledge. This study was conducted within the curriculum framework, as it is linked with the Biology and Chemistry syllabi. Nine (9) Biology and Chemistry teachers and ten (10) scientists from the Department of Chemistry and Biological Science Institute at a university situated in Kuala Lumpur, Malaysia, were involved in this study.

The schools were purposively selected, and the selection of schools was based on 'typical case sampling' simply because such schools were by no means unusual, and reflected the average phenomenon of interest (Merriam, 2009). Prior to commencing the study, ethical clearance was sought from the participants. Teachers and scientists volunteered to take part in the study and were assured of confidentiality and privacy. They were also required to fill out an informed consent form as proof of their willingness to participate in the study and their availability for interview sessions. In terms of this study, the teachers in this partnership played their role as mediators, instructional designers and involved in synchronization of scientific concepts and terminologies with the scientists.

The study involved three phases and took almost two (2) years to complete. The procedures are explained according to the following phases: (i) planning phase; (ii) action phase; and (iii) result phase. The planning phase was the phase where the scientists and teachers worked together to determine the suitable Chemistry and Biology concepts to be implemented in this study. The scientists' research project was mapped according to the Chemistry and Biology syllabi, and teachers utilised their knowledge to make the concepts comprehensible to Grade 10, secondary school students. This approach that bridged the current science syllabi with the scientists' field of expertise can be considered as a novel approach, as it has never been implemented in any STSP research to date.

In this study, the scientists who participated in the Chemistry subject were experts in natural products, and the scientists in Biology subject are neuroscience experts. The teachers and scientists worked together to developed two resource guides for those subjects (refer to Figure 1). The resource guides were validated by two expert teachers and a scientist in the respective STEM fields. The feedback from the experts was used to improve the resource guide before its implementation in the next phases.

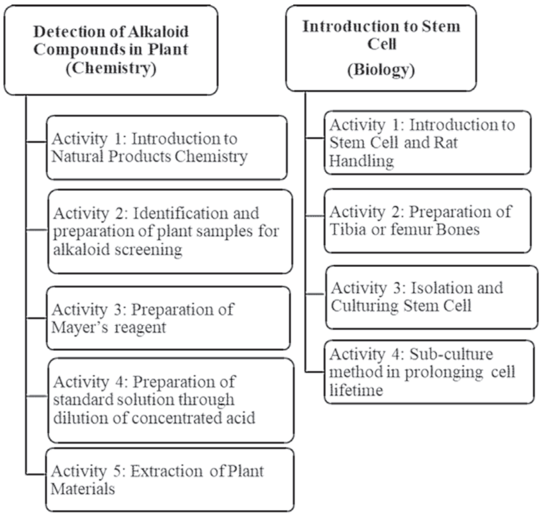

Figure 1. List of Activities in Biology and Chemistry Resource Guides

In the action phase, teachers in this study were trained at the university's laboratories by the Biology and Chemistry scientists. Teachers were then given the opportunity to conduct hands-on practical sessions according to their field, based on the developed resource guide. For example, for Biology, the teachers were trained in harvesting bone marrow from mice and isolating the stem cell from the bone marrow. In Chemistry, the teachers were trained in the extraction of plant parts (i.e., *Catharanthus roseus*) such as the bark and rhizome to detect the presence of alkaloids.

The action phase continued with the implementation of the activities based on the resource guides with the students at the selected schools. At the schools, the teachers demonstrated the activities to the students, facilitated by the scientist. The students were then given the opportunity to visit the university's Faculty of Science which allowed them to conduct more hands-on activities with the scientists based on the activities from the resource guide as well.

In the result phase, data were collected from the teachers, scientists, and students. The perceptions of each group were gathered through interviews and a survey. However, in this particular paper, only the perspective of the teachers and scientists, collected through individual interviews will be discussed in detail, in order to support the teachers' experiences in the context of professional development. Some of the examples of interview questions are as follow; what is your opinion regarding the activities conducted in this programme?; what do you think of the collaborative project or partnership between teachers and scientists? Is it viable?; what are the issues that you have encountered? how can you improve it?; and what do you think about the impact of this collaboration on your professional development?

Data were collected through observation during the activities and interviews. Semi-structured interviews were employed, and the interview sessions were conducted after the teachers had completed the STSP programmes. The researchers ensured that the time lapses between the teachers' completion of the STSP programmes and the interview session were not too long so that the teachers were able to recall the activities they had performed earlier. Collected data were analyzed using constant comparative analysis (Corbin & Strauss, 2015). This is consistent with the view that refining the thematic framework of the study involves logical and intuitive thinking to ensure that the research objectives are properly addressed (Merriam, 2009). Using research questions to guide the analysis , the data were encoded using open coding, axial coding, and selective coding. For instance if one excerpt is given the label 'teachers understanding of STEM', the researchers examined the observation data for other relevant excerpts that should be given the similar code. If reference was made to the same category again, the excerpt relating to the 'teachers understanding of STEM' were compared and contrast in order to find out what the commonalities, differences, and the dimension of the highlighted code.

Qualitative researchers need to maintain rigor, without compromising qualitative data relevance. In this study, the topics identified during the data analysis were evaluated through the peer review process to enhance the credibility and reliability of the qualitative study through the use of external peers. This study also employed data triangulation in the form of the interviews of scientists and teachers and classroom observations. As suggested by Merriam & Tisdell (2015), engaging multiple methods will render the data to be more reliable, accurate and trustworthy and they may reduce the uncertainty of the interpretation.

RESULTS AND DISCUSSION

Three (3) themes emerged from the analysis of the teachers' and scientists' interviews and the researcher's observation notes from the teachers' professional development perspective. The themes stressed that the partnership: (i) enhanced the teachers' understanding of cutting-edge STEM knowledge; (ii) elevated the teachers' confidence and enthusiasm for STEM; (iii) provided opportunities for information exchange and support through school-university networking.

The teachers in this study agreed that the partnership enhanced their understanding of the cutting-edge STEM knowledge and skills. During the interview session, teachers admitted that they lacked the up-to-date scientific skills in performing experiments since they basically performed experiments that only based on the current textbooks. In the Malaysian science curriculum, not many current experiments are introduced in the textbooks. Since graduating from their pre-service training, the teachers had limited opportunity to update their scientific knowledge, particularly in the latest development in the scientific discipline. Thus, the activities were found to be beneficial to the teachers, as they were relatable with the topic in the science syllabus, as mentioned in the following excerpt: Even though the topic of stem cell is not directly mentioned in the Form 4 (Grade 9) syllabus, it is certainly relatable. During the development of the activities, we have thoroughly discussed with the scientist to come out with a strategy to bridge the stem cell topic with Biology syllabus, as we need to make it understandable for the students (T.SK2, ln. 27-32).

The study also found that science teachers were able to contextualise the curriculum with cutting-edge STEM knowledge and real-world applications, specifically in stem cells and natural plants. Compared to most of the studies in STSP that are 'one-off' in nature, this study has provided opportunities for the teachers to engage in the development of learning resources. The resources included the instructional materials in catering to the needs of their students as well as the teachers. Thus, the strength of this particular study is that it connected teachers and scientists with the current science curriculum and extension to the content in the curriculum. The scientist in this study, also emphasized that teachers need to have "vast knowledge in scientific theories, learn and apply them in their science instruction" (Sc.D. ln. 23-25). Through this strategy, the teachers felt more engaged with the STEM concepts, as reflected from the following excerpt: I felt that it helps to enhance my understanding of the topic, and I can conduct interesting activities for my students based on the gained knowledge (T. SPA2, ln. 55-57).

The teachers agreed that their scientific skills had increased as a result of their participation in STSP. A teacher mentioned that "it is hard for us to get proper training especially when it comes to the enhancement of our laboratory skills. Thus, we really benefitted from this collaboration" (T. TPG1.ln.125-130). The teacher even confronted that she has "learned many things, even the simple thing such as the various ways of folding filter paper" (T.SA2. ln. 66-67).

The teachers stated that their involvement in the laboratory and interacting with the STEM scientists had given the appropriate knowledge and skills that were impactful for their teaching and learning practices. This may eventually lead to the enhancement of students' engagement and achievements in STEM-related subjects. The findings have shown that this partnership can be served as an effective platform for teacher's professional development training, where the teachers gained the necessary knowledge for teaching and learning.

The second theme that emerged from the findings is the teachers' level of confidence and enthusiasm for STEM. The teachers explained that they gained more confidence and more enthusiasm in teaching STEM-related subjects due to the exposure they gained from the partnership with the scientists. The teachers also mentioned that they appreciate STEM education more and became more confident in engaging their students through practical work, as outlined in the instructional materials. The teachers revealed that they were "exposed to innovative laboratory techniques and advanced equipment in Chemistry" (T. SAS1, ln.79) and the experience had improved their practical skills and STEM knowledge. The scientists have mentored them in acquiring new laboratory techniques such as the technique of extracting the stem cells from the femur of a lab rat and also extracting compounds from the plant *Catharanthus roseus,* commonly known as periwinkle.

The scientists also assisted the chemistry teachers during the lessons in their respective schools, especially during the extraction procedure, by facilitating the students during the extraction. These laboratory techniques were new to the teachers, and such collaboration has enhanced the teachers' confidence in handling the new laboratory techniques as well in teaching the edge-cutting STEM concepts. The following excerpt was taken from an interview with one of the Biology teachers: I had been given a chance to learn directly from the scientists during the workshop at the university's neurology laboratory. I dissected the rat and extracted the stem cell from the rat's bone marrow for my students, and the students conducted the experiment by themselves (T.SK1, ln. 28-30).

During the interview session with the scientists, they agreed that teachers were not confident due to a lack of training. The scientists understood the teachers' difficulties and uneasiness to conducting experiments with their students, as the scientific concept and skills are new to them, as explained by Scientist D in the following excerpt: At first, the teachers lack the confidence to do it (the activities) ... But once the teachers saw the way scientists conduct the activities, they became more confident (Sc.D. ln. 185-188).

By participating in the STSP programme, such experience helped the teachers to gain their confidence and enhance their enthusiasm to conduct STEM-related activities. Effective professional development should not only lead to the enhancement of understanding and knowledge, but it should also have an impact on the teacher's confidence that will later affect their science instruction. This research adds on to Schaffhauser's (2016) second domain concerned with teacher's professionalism, which emphasized teacher's autonomy in executing their work, such as curriculum choices, learning materials, and course content. Moreover, in this study, the teachers worked together with the scientists in determining the scope of the content, activities, and development of materials (resource guide).

This second theme also highlighted the teachers' understanding of the current career choices in STEM-related fields that affected their confidence in STEM through exposure provided by the scientists in this partnership. With a growing need for people with STEM-related skills in any nation's workforce, it is particularly important that students are made aware of the opportunities available as a result of studying the STEM subjects, and the different training options through new STEM career routes. Teachers in this study clarified that this partnership had increased their understanding of the current STEM-related jobs and career pathways, as mentioned in the following excerpt: Honestly, I did not really know how the researchers or scientists work. However, in this project, teachers and students were exposed on the exact way how the scientists conduct their research at this prestigious university. Thus, I think this programme has benefitted us as teachers so that we can give more information to the students that are interested in pursuing their career as scientists in numerous fields (T.TPG1. ln.95-97).

The teachers admitted that they were more passionate about STEM careers, and they were able to provide better-informed guidance on potential career choices in STEM to their students. They will become better counsellors in providing career guidance. Teachers who bridge science learning to careers in STEM can inspire students to fulfil their true potential. This will encourage the students to consider pursuing a STEM-related career in the future. One of the teachers shared that "some of my students are interested in becoming chemists after being involved with this project because chemists have the opportunity to conduct various experiments in the laboratory (T.SA1. ln. 312-315). Thus, it is important to equip teachers with the confidence and knowledge to embed STEM-related careers into science teaching.

Based on the interviews conducted with the teachers in this study, they agreed that the partnership was a productive and inspiring way of upskilling teachers' STEM knowledge and skills and enhanced their networking with higher education institutions. Schaffhauser (2016) highlighted the importance of networking and partnership in a professional development programme. Moreover, the teachers in this study were given the opportunity to support and directly contributed to the collaboration, as they took part in the development of the learning resources, i.e., the instructional materials, together with the scientists. Thus, this partnership instilled a sense of ownership and autonomy since they were involved directly with the development of the instructional materials.

Based on their experience of past collaborations with other universities, the teachers mentioned that they did not get any chance to be directly engaged with the programmes, as mentioned in the following excerpts: I think that collaboration was very effective because teachers were involved in developing the guides and implementing them in schools. We are not only assigned to escort the students alone (T.SAS1. ln.49-50).

One of the teachers in this study who teach in a 'High-Performance School' mentioned that this partnership is unique due to the specific engagement of the scientists with the teachers, students, schools, and the content of the science syllabus. 'High-Performance School' is a prestigious title conferred to a group of schools in Malaysia that have ethos, character, and a unique identity to excel in all aspects of education. The title is given by the Malaysian Ministry of Education (MOE). Due to this recognition, the school has been getting opportunities to be involved in numerous STEM activities with higher learning institutions. Still, STSP is relatively different from any of her previous experiences, as mentioned in the following excerpt: We always get the opportunity to be involved with universities… But this project differs, as the university builds relationships with schools more specifically. They connected the scientists with the teachers, and also with our students. That makes the project more unique as compared to other activities that I have experienced before… (T.SA1. ln.125-130).

The partnership enriched the teachers' experiences through exposing and providing them access to the scientific and research community. The teachers were given opportunities to not only gain but also share the latest scientific knowledge and skills while learning the value of working with the experts at the same time. Based on the data gathered during the interview with the scientists, many of them have given positive reactions to the teachers' commitment in this partnership, as mentioned by Scientist F and A: Teachers that I worked with were very committed. They shared useful information in term of biology curriculum expectation (Sc.F. ln. 41-42); They provided support and collaborate by providing information on what is being taught in the school and how we can integrate it with our research in university in the field of chemistry (Sc.A. ln. 53-55).

Therefore, the finding showed that this partnership was able to break the barriers between the schools and universities and provide networking for the teachers for information exchange and support, which aligned with the domain of teacher's professional development, as suggested by previous researchers. Initially, the teachers had shared that they felt inferior working alongside the academicians, especially those from universities. As a result of this partnership, the teachers realised that they "had gained a lot of experience from the experts in the fields of STEM" (T.SK2. ln.87-88).

The qualitative result provides evidence of the success of the STSP programmes as an effective professional development programme aimed at enhancing teachers' understanding and conceptualization of STEM knowledge and real-life applications of STEM concepts. Universities are knowledge and understanding centers that are particularly vital in the fast evolving fields of science, technology, engineering, and mathematics (STEM). While scientists excel in delving deeply into important scientific questions, they are significantly less proficient at sharing their skills, research findings, and awareness of societal ramifications with the rest of the world (Farah, 2019; Chandran et al., 2020). Successful partnerships between school and higher learning institutions have also been previously reported (e.g. Komoroske et al., 2015; Didden & Edmunds, 2016; Petersen & Chan, 2020).

The results of this study demonstrated that the tripartite partnership had been proven to enrich the teachers' experiences. The findings concurred with Yerrick and Beatty-Adler (2011) and So et al. (2020), who revealed that through direct contact with the scientists, the teachers would have high levels of engagement and active participation in STEM education. However, when comparing the result of this study to those of previous studies, the teachers found the STSP programmes were motivating (e.g., the involvement of the scientists), and this might have helped science teachers to make connections between the current scientific research and theory, and their classroom instruction. The teachers' conception of teaching STEM-related subjects positively changed once they had the opportunity to be involved in the partnership.

The first theme that emerged from the analysis illustrated that the partnership had enhanced the teachers understanding of the cutting-edge STEM knowledge and skills. Teachers reported that there is an improvement in understanding science curriculum, and this finding resonates with the studies by Brawley et al. (2008) and Johnson (2017). Brawley et al. (2008) and Yerrick and Beatty-Adler (2011) in findings explained that teachers' knowledge and experience appeared to have improved, and they were able to facilitate a better student learning process. Teachers need to further develop their understanding of the STEM concepts as part of their professional development programme as reiterated by Mansour (2015). He claimed that STSP provides further insight into the practice of science in a real-world context. Previous studies (e.g., Mustafa et al., 2016; Fadzil & Saat., 2017) found that despite science subjects, teachers are held responsible for teaching STEM. They are not having comprehensive STEM education instruction. In addition, the present science teacher education programme focused exclusively on specific disciplines, which contradicted the fundamental concepts of STEM teaching (Mustafa et al. 2016). It should be taken into account that STEM education is relatively new in Malaysia and that a substantial amount of time is needed for science teachers to develop a coherent understanding of its content in order to effectively apply STEM pedagogical approaches in the classroom. Moreover, some of the implementations of professional development programmes are ineffective and inappropriate for the teachers as they are not related to their field. Dong et al. (2019) and Geng et al. (2019) stated that among the common characteristics of effective professional development practices in high-achieving countries is that it should be specifically embedded in teachers' contexts and that are on-going over a period of time. Professional development training should also support the active involvement of teachers in the programme. These characteristics have been reflected through STSP programme.

The second theme in the study illustrated the teachers' views of the partnership where STSP has elevated the teachers' confidence and enthusiasm for STEM. However, the teachers also admitted that their limited knowledge of the STEM topics had made them rely significantly on the scientists' expertise during the preliminary study of this programme. Toto et al. (2021) also argued that STEM teachers have lack understanding of STEM education as teachers struggle to draw linkages between STEM disciplines and skills. The Biology and Chemistry scientists in this study understood the teachers' difficulties and uneasiness to conduct the experiment initially, and they were committed to assisting the teachers throughout the programme. This is coherent with Taylor et al. (2008) study that found that scientists were concerned about the quality of STEM education, and this might be due to the lack of hands-on activities and resources available for science instruction.

However, once the teachers applied and implemented the knowledge gained from the scientists, it increased their confidence in teaching STEM-related subjects. This eventually let them develop a positive attitude towards STEM as an approach to teaching science (Shein & Tsai, 2015; Farah, 2019). The finding found that teachers gained more confidence when they were exposed to direct, hands-on experience of working with scientists in the laboratory, where the thinking and doing of science were more realistic and mirrored the authentic science. The teachers found the relevance of the activities in the current scientific world rather than mere learning from the textbooks. Moreover, the teachers expressed their gratefulness because they were given the opportunity to support and directly contributed to the collaboration, especially when they take part in the development of the learning resources, i.e., the instructional materials, with the scientists. The finding showed that this partnership instilled a sense of ownership and autonomy to the teachers. This is not commonly observed in other professional development programmes that usually are based on a short training session. Liu & Phelps (2019) argued that for gains in knowledge to have an effect on teaching, these knowledge gains must persist. This has made STSP unique and more effective for teachers in a professional development point of view.

This second theme also explained the increased understanding among the teachers about current career choices in STEM-related fields. The results of this study showed that the teachers had limited STEM career knowledge with regard to the subject requirements and the type of activities involved in those careers. Blotnicky et al. (2018) found that providing students with an appreciation of STEM professions and the essence of STEM work is imperative for teachers. Exposing students to STEM careers can enhance their interest in pursuing careers involving science, technology, engineering and mathematics. The teachers in this study admitted that they were more passionate about STEM careers, and they were able to provide better-informed guidance on potential career choices in STEM to their students, after their involvement with this study. This finding concurred with Johnson (2017) which reported that when the teachers managed to expose their students to STEM-related careers, the students' interests in STEM had increased. This encouraged the students to consider pursuing a STEM-related career in the future. Teachers who bridge science learning with the profession in STEM can inspire students to fulfil their true potential. They will become a better counsellor in career guidance. Thus, it is important to equip teachers with the confidence and knowledge to embed STEM-related careers into the science teaching, as mentioned by previous researchers (e.g., Schaffhauser, 2016) who highlighted the importance of having the necessary knowledge for teaching STEM.

The third theme in this study was related to the networking and bridging between schools and higher education institutions. The finding highlighted that communication and partnership between teachers and scientists serve as an avenue for teachers to learn what is the current research in the field of science or STEM-related subjects. STEM is a fast-moving discipline. Consequently, teachers need to keep abreast of this rapid development in STEM-related fields. On the other hand, scientists will no longer be working *in-silo* where only their circle or the scientific community would understand their research and be aware of the latest development in the field. The networking provides opportunities for information exchange and support among the teachers and scientists and also between teachers from different schools who were involved in this project (Schaffhauser, 2016). However, one of the biggest challenges in STSP was in scheduling dedicated partnership time. To address this concern, this study had relied on technology (e.g., through the use of Whatsapp and Google Docs as a means of communication between teachers and scientists. The use of technology has enhanced communication and support the linking between teachers and scientists, which enabled them to work effectively during this project. Communication not only refers to physical communication during the project, but it includes linking the scientists and teachers or creating comradeship between them. Research by Chandran et al. (2020) found that partnership between teachers and scientists in professional development activities may encourage teachers to implement inquiry-based which include STEM-related activities in the classroom.

CONCLUSION

Becoming an effective science teacher is a continuous cycle that extends from the experience of pre-service in the undergraduate years to the end of one's career. Overall, the findings of this study suggested that the teachers are optimistic about the STSP collaboration as a teacher professional development initiative that provides the science teachers with opportunities to learn new knowledge and skills in STEM from the scientists. The teachers become more confident to implement the acquired knowledge and skills into their classrooms. Teachers participating in this study have also described a range of barriers that hinder them from incorporating STSP into their classrooms. Not surprisingly, time constraints and the need to prepare students for examination have been commonly identified by teachers as impediments to implementing the STSP programme. Other barriers include concerns about the viability and sustainability of this study. Although the scientists and teachers showed high levels of personal commitment, the question of longer-term viability of institutional commitment. On the other hand, the teachers express that they need more training because of the lack of skills in handling the experiment in the laboratory. Despite these obstacles, it can be deduced that all of the teachers who participated in this study are interested in implementing STSP. This is because it allows them to benefit from the programme, in terms of enhancing their knowledge and skills in STEM and increasing their motivation in teaching STEM-related subjects. However, further study can be conducted to study the effectiveness of STSP as an instructional approach and what it can offer for the future of STEM education. Professional development is a constant, lifelong phase for a science teacher. The process of transforming schools requires that opportunities for professional development within the school context be specifically and adequately connected to the work of STEM teachers.

REFERENCES

Aldahmash, A. H., Alshamrani, S. M., Alshaya, F. S., & Alsarrani, N. A. (2019). Research trends in in-service science teacher professional development from 2012 to 2016. *International Journal of Instruction, 12*(2), 163-178.

Barr, S., & Askell-Williams, H. (2020). Changes in teachers' epistemic cognition about self–regulated learning as they engaged in a researcher-facilitated professional learning community. *Asia-Pacific Journal of Teacher Education*, *48*(2), 187–212.

Blotnicky, K. A., Franz-Odendaal, T., French, F., & Joy, P. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International Journal of STEM Education*, *5*(1), 1-15.

Brawley, S. H., Pusey, J., Cole, B. J., Gott, L. E., & Norton, S. A. (2008). A revolutionary model to improve science education, teachers, and scientists. *Maine Policy Review*, *17*(1), 68-80.

Chandran, K. B., Jarrett, K., & Wyss, J. M. (2020). Creating a sustainable partnership between a science center, university, and local school districts: A retrospective on over 20 years of successful programming and partnership. *Journal of STEM Outreach*, *3*(3), 1-15.

Corbin, J., & Strauss, A. (2015). *Basics of Qualitative Research.* Thousand Oaks, California: SAGE Publications.

Didden, C., & Edmunds, P. J. (2016). Experiential ecological investigations as a vehicle coupling teaching & research in high schools & universities. *American Biology Teacher, 78*, 278–284.

Dong, Y., Xu, C., Song, X., Fu, Q., Chai, C. S., & Huang, Y. (2019). Exploring the effects of contextual factors on in-service teachers' engagement in STEM teaching. *The Asia-Pacific Education Researcher*, *28*(1), 25-34.

Fadzil, H. M., & Saat, R. M. (2017). Exploring students acquisition of manipulative skills during science practical work. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(8), 4591-4607.

Fadzil, H. M., Saat, R. M., Awang, K., & Hasan Adli, D. S. (2019). Students' perception of learning STEM related subjects through Scientist-Teacher-Student Partnership (STSP). *Journal of Baltic Science Education, 18*(4), 537-548.

Falloon, G. (2013). Forging school–scientist partnerships: A case of easier said than done?. *Journal of Science Education and Technology*, *22*(6), 858-876.

Farah, Y. N. (2019). Collaborative partnership: opening doors between schools and universities. *Gifted Child Today, 42*(2), 74–80.

Gallant, D. J. (2010). Science, technology, engineering, and mathematics (STEM) education. *Ohio State University*.

Geng, J., Jong, M.S.Y. & Chai, C.S. (2019). Hong Kong teachers' self-efficacy and concerns about STEM education. *The Asia-Pacific Education Researcher, 28*(1), 35-45.

Johnson, O. (2017). *A shift in scientific identities: How teacher-scientist partnerships can impact middle school teachers' science teaching and instruction.* North Carolina: The Friday Institute for Educational Innovation.

Komoroske, L. M., Hameed, S. O., Szoboszlai, A. I., Newsom, A.J. & Williams, S.L. (2015). A scientist's guide to achieving broader impacts through K–12 STEM collaboration. *BioScience, 65*, 313.

Liu, S., & Phelps, G. (2019). Does teacher learning last? Understanding how much teachers retain their knowledge after professional development. *Journal of Teacher Education*, *70*(5), 1-14.

Mahmud, S. N. D., Nasri, N. M., Samsudin, M. A. & Halim, L. (2018). Science teacher education in Malaysia: challenges and way forward. *Asia-Pacific Science Education*, 4, Article 8.

Mansour, N. (2015). Science teachers' views and stereotypes of religion, scientists and scientific research: A call for scientist–science teacher partnerships to promote inquiry-based learning. *International Journal of Science Education*, *37*(11), 1767-1794.

Merriam, S. B. (2009). *Qualitative Research: a guide to design and interpretation*. Jossey-Bass.

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

Mustafa, N., Ismail, Z., Tasir, Z., & Said, M. N. H. M. (2016). A meta-analysis of effective strategies for integrated STEM education. *Advanced Science Letters, 22*(12), 4225-4228

OECD (2009). *Teaching and learning international study (TALIS)*. Paris: Organisation for Economic Cooperation and Development.

Petersen, J., & Chan, P. (2020). A college–high school collaboration to support authentic microbiology research. *The American Biology Teacher*, *82*(4), 201-208.

Permanasari, A., Rubini, B., & Nugroho, O. (2021). STEM Education in Indonesia: Science Teachers' and Students' Perspectives. *Journal of Innovation in Educational and Cultural Research, 2*(1), 7-16.

Ramli, N. F., & Talib, O. (2017). Can education institution implement STEM? From Malaysian teachers' view. *International Journal of Academic Research in Business and Social Sciences, 7*(3), 721–732.

Reston, E., Krishnan, S., & Idris, N. (2014). Statistics education research in Malaysia and the Philippines: A comparative analysis. *Statistics Education Research Journal*, *13*(2), 218-231.

Roehrig, G. H., Dare, E. A., Ring-Whalen, E., & Wieselmann, J. R. (2021). Understanding coherence and integration in integrated STEM curriculum. *International Journal of STEM Education*, *8*(1), 1-21.

Rutkowski, D., Rutkowski, L., Bélanger, J., Knoll, S., Weatherby, K., & Prusinski, E. (2013). Teaching and Learning International Survey TALIS 2013: Conceptual Framework. Final. *OECD Publishing*.

Schaffhauser, D. (2016). OECD: Teacher professionalism needs improvement worldwide. *The Journal*.

Shein, P. P., & Tsai, C. Y. (2015) Impact of a Scientist–Teacher Collaborative Model on students, teachers, and scientists. *International Journal of Science Education, 37(*13), 2147-2169.

Siew, N. M., Amir, N., & Chong, C. L. (2015). The perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science. *SpringerPlus, 4*(1), 1–20.

Sun, Y., Rogers, R. R., & Winship, J. M. (2019). An authentic and sustainable STEM pre-service teacher professional development model: authentic learning experience and preparing for tomorrow's STEM professionals. In *Handbook of Research on Educator Preparation and Professional Learning* (pp. 321-339). IGI Global.

Taylor, A. R., Jones, M. G., Broadwell, B., & Oppewal, T. (2008). Creativity, inquiry, or accountability? Scientists' and teachers' perceptions of science education. *Science Education*, *92*(6), 1058-1075.

Tong, W., & Razniak, A. (2017). Building professional capital within a 21st century learning framework. *Journal of Professional Capital and Community*, *2*(1), 36-49.

Toto, T., Yulisma, L., & Amam, A. (2021). Improving teachers' understanding and readiness in implementing STEM through science learning simulation. *Jurnal Pendidikan IPA Indonesia*, *10*(2), 303-310.

So, W. M. W., He, Q., Chen, Y. & Chow, C. F. (2020). School-STEM professionals' collaboration: A case study on teachers' conceptions. *Asia-Pacific Journal of Teacher Education*, *49*(3), 300–3018.

Yerrick, R., & Beatty-Adler, D. (2011). Addressing equity and diversity with teachers though informal science institutions and teacher professional development. *Journal of Science Teacher Education*, *22*(3), 229-253.