

STUDENTS' PERCEPTION OF LEARNING STEM-RELATED SUBJECTS THROUGH SCIENTIST-TEACHER-STUDENT PARTNERSHIP (STSP)

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Introduction

In this digital revolution where science and technology play a fundamental role in our lives, STEM education is facing a great challenge. The ability to address 21st-century challenges such as climate change, poverty and food security will depend on how well-educated the population in STEM is. However, in most countries, there has been a decrease in the number of students pursuing Science, Technology, Engineering and Mathematics (STEM) related fields in secondary school and tertiary education level (Alan, Zengin, & Kececi, 2019; Ergün, 2019; Halim & Meerah, 2016; Jaremus, Gore, Fray, & Prieto-Rodriguez, 2019). Recent studies have shown that engagement with school science and motivation to choose science related career among secondary school students are alarming, as students reject science related career as a future career option (Kudenko & Gras-Velázquez, 2016; Shao-Na Zhou et al., 2019; Van Griethuijsen et al., 2015). Many students in secondary school and post-secondary were switching from STEM majors to other fields (Shao-Na Zhou et al., 2019). According to Gilbert and Justi (2016) evidence of students' lack of engagement in science classes is used to support widespread dissatisfaction regarding students' levels of attainment in international studies such as TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment). In addition, Carnevale, Smith and Melton (2011) found that only half of those students who originally studied STEM majors actually completed STEM degrees. This has led to concern among policymakers about their nation's science and technology workforce, as well as the scientific literacy of their populations (Van Griethuijsen et al., 2015). For example, in the case of Malaysia, the decrease in the number of students in the science stream is alarming and this may lead to a serious human capital shortage in the STEM field if the number of students who enrol in STEM courses does not meet its expected standards, which is at 270,000 per year or 60% of the annual national cohort (Academy of Sciences, 2017). To address this declining enrolment, science education needs to be more relevant in order to ensure that students have positive attitudes and interest towards STEM-related subjects.



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Abstract. *Science education is facing an immense challenge due to students' lack of engagement with science education. This issue calls for a collaborative and integrative teaching strategy such as the Scientist-Teacher-Student Partnership (STSP). This research employed a qualitative research methodology supported by quantitative data, to explore students' perceptions of learning science through STSP. It involved 125 students in Grade 10 from four schools, eight science teachers and seven scientists from a university situated in Kuala Lumpur. The data were collected through survey questionnaire and interviews. The collected qualitative data were analysed using constant comparative techniques and the quantitative data arising from the responses of the survey were calculated as mean scores and standard deviations. The findings showed that the tripartite collaboration brings educational benefits to all groups. Based on the student' perspective, four (4) main themes emerged. The students found that 1) the partnership enriched their learning experiences, 2) they acquired procedural skills through hands-on experiments, 3) they had the opportunity to explore emerging topics in science, and 4) they were exposed to various career opportunities in STEM-related fields. This research has promoted greater articulation of STSP as a mechanism for educational reform in STEM.*

Keywords: *authentic science, qualitative methodology, Scientist-teacher-student partnership (STSP), STEM.*

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Among the possible factors that contribute to this phenomenon is the decline of interest in science that contributed to decrease number of students pursuing STEM, ineffective teaching methodology, ad-hoc changes in policies and low level of awareness of the demand for specialised talent in STEM. According to Williams (2013), students give up on science for various reasons. Some perceive science as being too hard; some are afraid to make mistakes and fail, and some are not willing to devote the effort required to prepare themselves to attain a STEM career. Compared to other subjects, science learning involves laboratory work, and it is always considered as the essence of science. Students should perform experiments in the quest of scientific knowledge. However, according to studies, (e.g. Abrahams, Reiss, & Sharpe, 2013; Fuccia, Witteck, Markic, & Eilks, 2012; Fadzil & Saat, 2017) experimentation is still limited in many science classrooms due to lack of resources. Studies also show that students are not interested in science due to the way science is taught. Many are not performing hands-on activities as students envisioned and their science teachers are not competent in teaching science, especially using scientific inquiry and investigation (Alan, Zengin, & Kecici, 2019; Fadzil & Saat, 2013). Schools are also deprived of quality science teachers. Many of these teachers adopt a "cookbook" style in teaching science (Abrahams, Reiss & Sharpe, 2013; Schwichow, Zimmerman, Croker, & Härtig, 2016).

Recent studies have also shown that one of the factors that affected the decline of student's interest in STEM-related careers is the lack of awareness of the wide range of careers that students can enter with a science background (e.g. Ergün, 2019; Peker & Dolan, 2012). Due to the lack of access to the real STEM profession opportunities, students are unable to see these disciplines as springboards for their careers. Thus, students need to be able to relate the required skills and competences needed in those careers to their own skills and interests, helping them to make decisions about their future studies and careers. According to Salonen, Hartikainen-Ahia, Hense, Scheersoij and Keinonen (2017), student's perceptions of STEM and life skills will allow them to make links between their own scientific knowledge, science in society and scientific careers. Thus, one of the ways to address these issues is to demonstrate 'real' or 'authentic' science to students (Houseal, Abd-El-Khalick, & Destefano, 2014; Ufnar & Shepherd, 2018) through the Scientist-Teacher-Student Partnership (STSP) where teachers and students acquire science knowledge and scientific skills in 'real' investigations from scientists. Previous findings in Scientist-Teacher-Students Partnership (STSP) showed that students appeared to learn more as a result of having hands-on experience as they get more opportunities to expose them to authentic learning with scientists (Houseal, Abd-El-Khalick, & Destefano, 2014; Tanner, Chatman, & Allen, 2003; Ufnar & Shepherd, 2018).

Collaboration or partnership between the scientific community and science educators has become an increasingly popular approach in science education reform (Adams & Hemingway, 2014; Houseal, Abd-El-Khalick, & Destefano, 2014; Shein & Tsai, 2015). Scientist-Teacher-Student Partnership (STSP) in this study refers to a collaboration among upper secondary science teachers and university scientists which involves mutual learning via a partnership. Previous studies have shown that the tripartite collaboration brings educational benefits to all groups. For teachers, this partnership provides insight to the scientific inquiry process, extending their content knowledge and pedagogical strategies, and renews their teaching (Houseal, Abd-El-Khalick, & Destefano, 2014; Tanner, Chatman, & Allen, 2003; Ufnar & Shepherd, 2018). The term *scientist-educator* has been coined by Tanner, Chatman and Allen (2003) to represent hybrids individuals who have experience in both professional cultures: science and science education. Benefits for scientists include enhanced communication and pedagogical skills (Tanner, Chatman, & Allen, 2003) and for students, the partnership enriches their learning experiences by providing access to the scientific community and content knowledge gains, which in turn improves their science performance (Houseal, Abd-El-Khalick, & Destefano, 2014; Tanner, Chatman, & Allen, 2003). This partnership might offer the flexibility to provide students with opportunities to explore science topics that encourage the development of students' interest and to focus on the development of skills that are covered thoroughly in class, as suggested by Newell et al. (2015).

While such partnership appears to provide benefits for teachers, scientists, and students, there are also issues and challenges that need to be considered. According to studies by Peker and Dolan (2012), and Tanner, Chatman, and Allen (2003), scientists find that the school world is foreign to them and teachers are also not familiar with scientists' scientific culture. Houseal, Abd-El-Khalick and Destefano (2014) also discussed the difficulties in developing and maintaining the mutual partnership. Thus, various designs of the scientist-teacher partnership have been adopted including scientist-teacher mentorships, workshops, science camps and award programs (Falloon, 2013). Extensive knowledge of how these partnerships work is essential, especially in the context of the students' perception of it. Students act as the end receiver of the skills and knowledge transferred by teachers and scientists. Claudio (2001) in his research found that students in his study perceived science as serious and not enjoyable, and



that science is proven through a variety of incomprehensible practices. However, this conception has changed in a positive direction after the students got the opportunity to involve themselves in scientist-teacher partnership programs. Previous studies (e.g. Shein & Tsai, 2015; Ufnar & Shepherd, 2018) also revealed that students who are given the opportunity to learn from scientists become more motivated to learn science. Thus, the importance of this collaboration should not be undervalued in the efforts to reform science education. While this mutual learning approach appears to be ideal for science and STEM education, unfortunately, there are limited mechanisms that support this cross-institutional partnership. Most of the studies focus on the scientists-teachers' collaboration and not much work has been done in understanding how such partnership influences the students' science learning (Adams & Hemingway, 2014; Houseal, Abd-El-Khalick & Destefano, 2014; Peker & Dolan, 2012; Sadler et al., 2010; Tanner, Chatman & Allen, 2003). The purpose of the present research is, therefore, to explore the students' perception of learning STEM-related subjects through scientist-teacher-student partnership (STSP) programs. This research focused on the following research question: How do the students' perceived learning STEM-related subjects through scientist-teacher-student partnership (STSP) programs?

Research Methodology

General Background

This research employs a qualitative research methodology supported by quantitative data to explore students' perspectives regarding the scientist-teacher-student partnership. The researchers attempt to identify how these STSP programs can bring benefit to enhance students' interest in learning STEM-related subjects at secondary school. This research was conducted within the curriculum framework, as it is linked with the current science syllabi. However, some of the activities were carried out outside of the formal school time such as on Saturday.

Participants

This research involved 125 students in Grade 10 from four schools, eight Biology and Chemistry teachers and seven scientists from the Department of Chemistry and Biological Science Institute at a university situated in Kuala Lumpur, Malaysia. The schools were purposively selected, and the selection of schools was based on 'typical case sampling', simply because these schools were not unusual in any way and it reflected the average phenomenon of interest (Merriam, 2009). Prior to commencing the research, ethical clearance was sought from the participants. They volunteered to take part in the research and were assured of their confidentiality and privacy. They were also required to fill an informed consent form as proof of their acceptance to participate in the study. In term of this research, students in this partnership played their role as the end user of the collaboration. The students gave their feedback to the activities conducted by the teachers and scientists through the survey questionnaire during the interview session.

The Procedure of the Research and Data Collection

The research involved three phases and took almost two (2) years to complete. The procedures will be explained according to the following phases: (i) planning phase, (ii) action phase and (iii) result phase. The *planning phase* is the phase where scientists and teachers work 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 the 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 participating in Chemistry subject are experts in natural product and the scientists in Biology subject are neuroscience experts. The teachers and scientists worked together to develop two resource guides for those subjects, namely "Introduction to Stem Cell" for Biology and "Detection of Alkaloid Compounds in Plant" for Chemistry. The resource guides consisted of four to five activities related to the topic (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. For example, more suitable scientific terminologies have been used in the resource guides, and the procedures



have been simplified so it will be clearer for secondary school students to comprehend.

During this planning phase, the researchers found that the duties of teachers and scientists make it difficult for them to find the time and space to cultivate the partnership. Thus, it is important for the researchers to carefully plan the data collection activities in the action phase because there had been challenges in scheduling a dedicated partnership between the teachers and the scientists. However, the use of technology enhanced the communication strategies for teachers and scientists, especially during the development of instructional materials that required full commitment and expertise from both parties.

In the second phase, the transfer of skills occurred. In the *action phase*, teachers in this study were trained at the university's laboratories by the Biology and Chemistry scientists. Before the hands-on training session begins, the scientists explained the essential concepts related to stem cells and extraction of alkaloids compound to the teachers, so that they understand the underlying principle of the related topic. 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 teams also took the initiative to produce a video to demonstrate a step-by-step procedure, as a guide for the teachers. This is to ensure that the activities in this resource guide can be conducted by teachers, even without the assistance of the scientist.

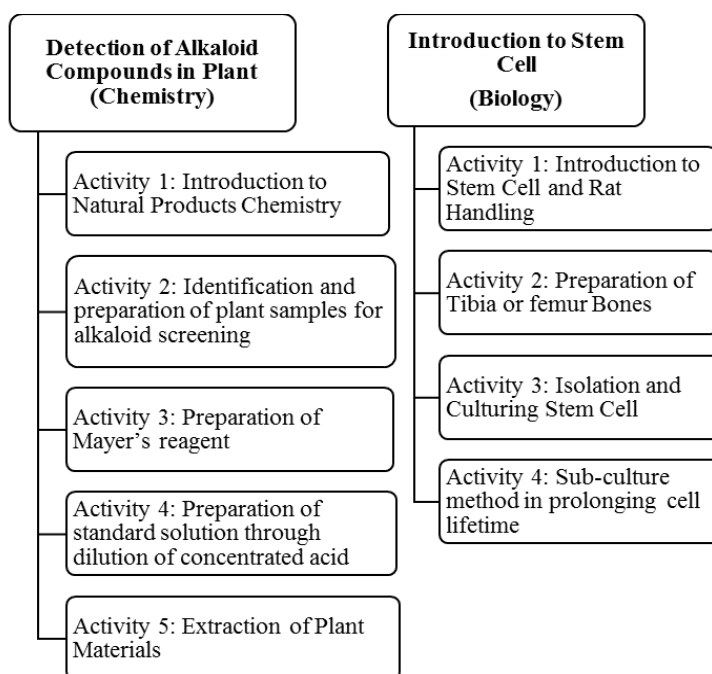


Figure 1. List of activities in Biology and Chemistry resource guides.

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. Students were then given the opportunity to visit the university's Faculty of Science and conduct more hands-on activities with the scientists based on the activities from the resource guide as well. The activities were done outside of the formal school time.

In the *result phase*, data were collected from the teachers, scientists and students. The perceptions of each group were gathered through interviews and survey. The data were then qualitatively and quantitatively analysed. However, in this particular paper, only the insight of the students will be discussed in detail. The following figure (Figure 2) explains the flow of the research.

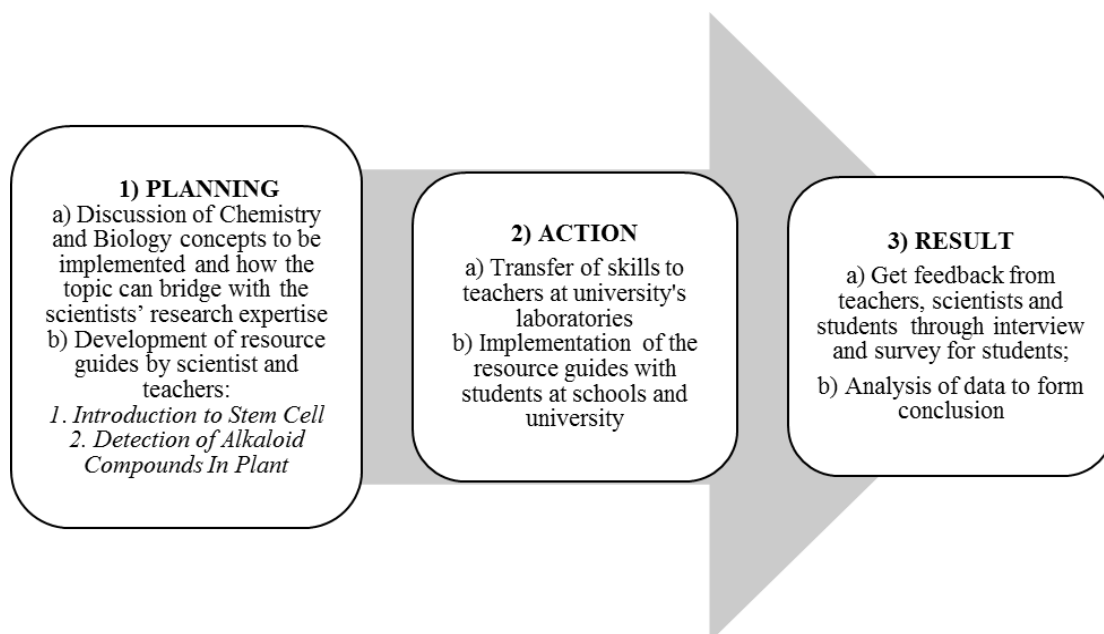


Figure 2. Flow of the research.

Data Analysis

To obtain a deeper understanding of the students' perception of this partnership, the qualitative data were collected through focus group interviews with all the participants of this research ($n = 125$). Semi-structured interviews (refer Table 1) were employed and the interview sessions were conducted after the students had completed the STSP programs. The researchers ensured that the time lapses between the students completing the STSP programs and the interview session were not too long so that the students were able to recall the activities they had performed earlier. The collected data were then analysed using constant comparative data analysis techniques for the researchers to recognise variations in patterns as the central phenomenon was investigated (Strauss & Corbin, 1998). This is in line with the view that refining the thematic framework of the research involves logical and intuitive thinking in making sure that the research objectives are being addressed appropriately.

Table 1. Student interview protocol.

Number	Question
1	Could you recall back the activities that had been done during the program?
2	What is your opinion regarding the activities conducted in this program?
3	Can the activities help you to understand science better? If yes/no, please explain.
4	Can you relate what you learn during that activity to what you have learn in school? Please explain.
5	What do you think about collaboration with the scientist?
6	What have you learnt from the scientist?
7	Do you have any issue working with the scientist?
8	Do you think that these programs can enhance your interest in learning science? If yes/no, please explain.
9	In what ways is this program preparing you for your science classes? Please describe.
10	If you were to involve in these programs again next year, what would you want us to do differently? Why?



A survey was also administrated to the students at the end of the study (n=125). In general, the items from the survey questionnaire sought to determine students' perception towards STEM-related subjects and this survey questionnaire was developed by the researchers based on the related literature. The questionnaire consisted of four constructs which are perception towards STEM-related subjects (n=5), intrinsic motivation (n=4), career motivation in STEM (n=4) and grade motivation in STEM-related subjects (n=5). In order to ensure the content validity of the questionnaire, all the items from the questionnaire were validated by four experts, including two professors in STEM-related field and two expert teachers. The inputs from the panel of experts were used to improve the quality of the items. The items were also checked in terms of its internal consistency. The questionnaire contained 18 items linked to a five-point Likert scale: strongly disagree [1], disagree [2], not sure [3], agree [4] and strongly agree [5]. Quantitative data arising from the responses of the survey were calculated using mean scores and the standard deviation for each item. For the purpose of this paper, only the first construct of the survey which is "the students' perception towards STEM-related subjects" after going through the STSP programs were analysed using descriptive statistics.

Validity and Reliability

While designing a qualitative research, validity and reliability are the two issues that a researcher should be concerned about. Qualitative researchers need to ensure rigour without sacrificing the relevance of the qualitative data. In this research, the themes identified during the data analysis were evaluated through the peer review process to enhance the credibility and trustworthiness of qualitative research through the use of external peers. Another approach implemented in this study was triangulation. Triangulation should support the findings by showing corroboration or a confidence interval, as claimed by Merriam (2009). Engaging multiple methods such as observation and interviews will lead to more reliable, accurate and trustworthy findings, and may reduce the uncertainty of the interpretation. The interviews and researchers' observation notes were also used in a triangulation method to support the findings of this study. In terms of the quantitative study, with respect to the reliability coefficient, the internal consistency (Cronbach's α) of the instrument in this study was 0.936. Thus, the survey was found to be highly reliable (18 items; $\alpha = .936$).

Research Results

The students' answers were fundamental to this research's findings. Table 2 illustrates the mean scores and standard deviation for the items under the construct "perception towards STEM-related subjects".

Table 2. Students' perception towards STEM-related subjects (n=125).

Items	<i>M</i>	<i>SD</i>
1. STEM-related subjects are my most favorite subjects	4.28	0.60
2. Activities held in this project gain my interest in learning STEM-related subjects	4.43	0.50
3. STEM is related to the daily life	4.55	0.50
4. Learning STEM-related subjects make my life become meaningful	4.23	0.56
5. I am interested to pursue STEM-related career	4.34	0.55

Based on Table 2, the mean scores are high for all the items. This suggests that students perceive STSP as an appropriate approach to be implemented in their teaching and learning of STEM-related subjects. Overall, students who participated in this research agreed that STEM-related subjects are their favourite subjects in school. The students also agree that the chemistry and biology activities carried out in this study have given them an interest in learning STEM-related subjects. The students in this study unanimously agree with the statement of item three which discusses STEM and its connection with daily life. They also agreed that their life has become more meaningful when they learn STEM-related subjects, and they were interested in choosing a career in STEM. The positive response from this quantitative finding will corroborate the themes that emerged from the semi-structured interviews. Four main themes emerged from the interviews. The students found that: 1) the partnership enriched their learning experiences, 2) they acquired procedural skills through hands-on experiments, 3) they had



the opportunity to explore emerging topics in science, and 4) they were exposed to various career opportunities in STEM-related fields.

STSP Enriched Students Learning Experiences

The partnership enriched the students' learning experiences through exposing and providing the students access to the scientific and research community. They were given opportunities to not only gain but also share the latest scientific knowledge and skills while learning the value of working with others at the same time. The partnership changed the students' perception about science, wherein before the partnership occurred, the students thought of the science subjects as static and limited which caused loss of interest in science among the students in the secondary school. From the interviews, the participants admit that they find Biology and Chemistry to be uninteresting and dreary subjects;

"I always like science and find it interesting, but when you go to school, you will find Biology, Chemistry are so boring..." (SA, In.348)

"I feel like 10th Grade syllabus is so dry, it is really bad" (SA, In.360)

Student: I think the second I join 10th Grade, I found myself losing interest in science

Researcher: Including biology?

Student: For me, it was biology (SA, In.470-474)

However, through this partnership, the students had the opportunity to participate in a lesson that required them to employ in-depth thinking and to become involved in a hands-on science experiment. These processes more realistically mirrored the practice of scientific communities, as reflected from the following excerpt,

"This scientist, he was studying the action of a nerve cell, neuron...how the stem cell could specialise in nerve cells..." (SAS, In.114-115)

"We definitely get to know more about research in natural products and what it's really about" (SA, In.432)

This was in accordance with the quantitative findings where the students agree that STEM-related subjects are their favourite subjects in school and the activities held in this study had given them an interest in learning STEM-related subjects, with $M=4.28$ and $M=4.43$ respectively.

Students Acquired Procedural Skills through Hands-On Exploration

From the data gathered during an interview with the scientists, many of them expressed their concerns about the quality of science education due to a lack of hands-on activities and opportunities to apply what they learn in science subjects to real-world contexts. This is supported by teachers' statement that high achievers are adept to rote learning and memorising of facts. However, the opportunity to engage in STSP has caused the students to be out of their comfort zone because different learning approaches are required. The findings have shown that through this study, students were able to use their prior scientific knowledge to make connections to their learning through the hands-on and minds-on explorations. Students acquired procedural skills through hands-on experiences at schools and university. It is reflected in the interview with the students:

"I think it was really cool, working with the scientist. I never get a chance to do dissection before. This is my first experience, and to know that we can harvest the stem cells from rat bone marrow..." (SAS., In 51-53)

"I felt that dissection part was a very good hands-on experience. I think that I have the talent to do it in real life" (SA., In.435-437)

"When we did not know how to do a certain task, the scientist came and taught us step by step on how to do it" (SK. In. 154-155)

Teachers support this finding by emphasising that the transfer of knowledge mostly comes from a hands-



on approach. Through a partnership with the scientists, the researchers observed high levels of engagement from the students in experimenting. Students appear to learn more as a result of having a hands-on experience. Furthermore, the science teachers state that the partnership gave chances for the students to have exposure to the "real world" science learning with scientists. Through this approach, the teachers report that there was an increase in the number of students engaged in science learning. The findings also indicate that students became gained exposure to the latest laboratory equipment and new skills and techniques, as explained by this student, "it was interesting...we were introduced to new technology. The machinery used in the university are different, we did not even know that it exists" (SA. In. 133-134). This is also reflected in the following excerpts:

"We look around to see how things done in proper lab, the atmosphere...It gives us some idea, if you want to do chemistry, what apparatus they use, how it looks like, the kind of project they do..." (SA. In. 129-132)

"Some of the steps that we conducted with the scientist is not stated in our text book, like filter paper cone folding techniques, the technique in adding chemicals to the crystal...we learn this from the scientist" (SA. In. 98-103)

The students expressed that they learnt more through hands-on exploration as they were able to use their prior knowledge to make connections to their learning. The teachers mediated the scientist's knowledge by linking new knowledge to the students' prior knowledge. Moreover, from the interview, the teachers stated that their experience working in the laboratory and interacting with the STEM scientist had given them appropriate knowledge and skills that were impactful to their teaching and learning practices and this may eventually lead to the enhancement of students' engagement and achievements in STEM-related subjects.

Students Had the Opportunity to Explore Emerging Topics in Science

The findings showed that students preferred to explore the latest emerging topics as they can gain and apply new knowledge. The students admitted that topics such as stem cells and natural products were interesting and exciting to them. As an extension of what they learnt in the present science syllabus, such topics can really spark the students' interest in learning STEM-related subjects, as explained by the following students:

"It is quite interesting to see such a simple concept can develop into an idea where we can help people from it" (SA In.159-161)

"I think we definitely learn interesting thing outside of our syllabus" (SAS, In.92)

"Alkaloid was not really in our syllabus, so it was the extra thing we can get from this. We quite grateful for that" (SA. In. 96-97)

Researcher: Do you think the topic should be taken from your syllabus...?

Student: I think it should be completely different from our syllabus...I

I think we have enough of it (SA, In.234-235).

However, some of the teachers were found to have the opposite view as they did not prefer to use emerging topics in teaching and learning. According to them, the topic was not directly related to the syllabus. Contrary to the finding from teachers' interview, the study has found that students were inspired to extend the knowledge that they have gained throughout this project. For example, the experiment in chemistry needed the students to conduct extraction of plants, i.e. *Catharanthus roseus* or commonly known as periwinkle. From the skills of extraction, the students have developed an idea to "extract the pigment of mulberry to make cosmetics such as lipstick" (SA. In. 183-184). The students mentioned that the experiment conducted in chemistry has "motivated us to utilise our own school laboratory and we actually started a project to create our own organic cosmetics. We got out inspiration from there" (SA. In. 38-41).

It can be summarized that the partnership affected students' competency whereby during the process, the scientists introduced new scientific concepts with real-life examples and socio-scientific impacts of the theory, as supported by the quantitative findings, where the students agreed that STEM had made their life more meaningful ($M=4.23$) and STEM was related to their daily life ($M=4.55$).



Gain Exposure to Various Career Opportunities in STEM-related Fields

According to the students, it had allowed them to be immersed in the scientific culture, where they can get direct knowledge and skills to understand what it means to become a scientist. The students assumed that their career path in science is limited; as it is either to be a doctor, dentist or pharmacist. This research had opened their mind regarding the career as a scientist, as indicated by the following excerpts:

"We could see how life actually is if we want to pursue science as a career" (SAS, ln.447)

"We definitely get to know more about scientific research and what it is really about if you were to pursue your career as scientist" (SA, ln.432-433)

"For some students who incline to go into this field of research, it was an eye-opening experience for them to decide if this what they want to do" (SA, ln.59-61)

"It gave us more insight, more direction to go into the field" (SK, ln. 102)

The quantitative findings also showed that the students were interested to choose a career in STEM with $M=4.34$. This might be related to this particular theme, where students were exposed to the STEM-related career. In this research, the students get to experience science in a more authentic setting through activities organised in these partnerships. The students also mentioned that they received genuine comments and feedback from the scientists regarding the career opportunity while engaging in this project.

Discussion

The qualitative and quantitative result provides evidence on how STSP programs enhanced the students' interests in learning STEM-related subjects. The results demonstrated that the tripartite partnership has been proven to enrich the students' learning experiences. The findings concurred with Yerrick and Adler (2011) and Claudio (2001), who revealed that through direct contact with the scientists, the students will have high levels of engagement and active participation. The students in this study viewed the scientists as their role model, and they tried to emulate the scientists. However, when comparing the result of this study to those of the previous studies, the students found the STSP programs were motivating (e.g. the involvement of the scientists) and this might have helped science teachers to make connections between current scientific research and theory, and their classroom instruction. The students' conception of STEM-related subjects positively changed once they got the opportunity to be involved in the partnership.

Previous studies in science education (e.g. Fadzil & Saat, 2017; Newell et al., 2015; Roberts et al., 2018) have shown that one of the other factor that influences students to opt out of science has to do with the fact that some students perceive the subject as being difficult to learn as compared to other subjects. Students get demotivated due to the high failure rate and poor grades. Low achievements during secondary school can also hinder students' abilities to pursue STEM-related programs and discourage the pursuit of education pathways aimed toward STEM-related careers (Newell et al., 2015). Many students have concluded that the STEM subjects are too challenging, yet boring and uninteresting, which limits their participation in STEM subjects and activities (Roberts et al., 2018). Chittum, Jones, Akalin, and Schram (2017) have identified interest and motivation as important components in inspiring students to pursue their study in STEM because it contributes to students' learning and success in retaining STEM content. Based on the findings of this study, the students expressed that the partnership changed their perception about science. They have gained latest scientific knowledge and skills through the STSP program. The partnership enhanced their interests and they became more motivated to learning STEM-related subjects. Moreover, students who have an increased interest in STEM are more likely to pursue that interest resulting in a STEM-related career, as suggested by Roberts et al. (2018).

Students' learning about STEM was more meaningful when they were able to interact with materials and apparatus. The finding also provides evidence to the students' acquisition of procedural skills through hands-on experiences at schools and university. Students commented on how the hands-on activities and experimenting made the content come to life. The experience gained from working in the laboratory had given them appropriate science knowledge and scientific skills and it has led the students to the enhancement of engagement in STEM-



related subjects. The findings also suggested that engagement in science learning was enhanced through the opportunity for students to have direct contact with the scientists and by allowing the students to assume an active role in inquiry during hands-on experimentation. However, as discussed earlier in the procedure of the study, one of the limitations in conducting hands-on exploration in this STSP study is the difficulty to accommodate dedicated partnership time between schools and university. This issue has also been raised in previous STSP studies (e.g. Evans et al., 2018; Peker & Dolan, 2012; Shein & Tsai, 2015; Yerrick & Adler, 2011) but little is known about the measures taken to address this challenge. Thus, to overcome this issue, the activities conducted in this study were carefully planned to suit both partners and efficiently organised by the researchers, so that students can conduct the activities within the time frame and obtain maximum benefits throughout the study.

The findings of the research also showed that students were thrilled to be given opportunity to explore the latest emerging topics in STEM, as they can gain and apply new knowledge in science. This is an important finding in understanding the students' view of learning science topic which was not directly related to the school syllabus. Surprisingly, teachers were found to be unsupportive in introducing the students to the latest emerging STEM topics. This might be due to the pressure of completing the science syllabus. On the other hand, the students agreed that the exposure to the STEM activities in the STSP programs had made their learning more meaningful and the knowledge gained is much related to their daily lives. This result ties well with previous study by Shein and Tsai (2015) that found that through the partnership, students gain new scientific knowledge and can apply such knowledge to solve problems in their daily lives. The study also confirmed the findings of Lasen et al. (2014), that the students' perception about STEM had changed through this partnership, as they perceived STEM-related subjects as an interesting subject that is relatable to their lives.

With a growing need for people with STEM-related skills in the country's workforce, it is particularly important that students should be well-informed of the opportunities available for them when pursuing STEM-related careers. The current study found that through this partnership, students gained exposure to various career opportunities in STEM-related fields especially in understanding what it means to become a scientist. Students were able to connect their new learning to their futures. Beforehand, the students assumed that their career path in science is very limited. The finding resonated with earlier works (e.g. Houseal, Abd-El-Khalick, & Destefano, 2014; Peker & Dolan, 2012; Sadler et al., 2010) that suggested that students who participated in the partnership were able to make better decisions about their future as the partnership relates to science and scientific careers. According to Ergün (2019), the STEM career interest of students can be developed in a positive manner by giving them sufficient occupational guidance about their STEM careers. Thus, STEM career awareness should be a focus for improvement in STEM education, as suggested by Knowles, Kelley and Holland (2018) and Salonen et al. (2017).

Conclusions

In the light of these findings, it can be concluded that STSP programs can bring benefit to enhance students' interest in learning STEM-related subjects at secondary school, as the partnership has been proven to enrich their learning experiences. In these programs, students acquired important procedural skills through hands-on experiments, and they had the opportunity to explore current emerging topics in science. The students were also exposed to various career opportunities in STEM-related fields. The findings demonstrated that the partnerships built between scientists, teachers and students could positively affect STEM education. It was discovered that the involvement of scientists in students' STEM education allowed the students to see the reality of science in real life setting and thus heightening their interest in STEM. However, for the students, these experiences needed to be real-life STEM education experiences that prioritise hands-on learning activities which can increase students' engagement in learning science. Further studies are needed to determine whether students' perception of STEM subjects change after having the opportunities to work with scientists for a prolonged duration, to determine the implications that this partnership may have for the future of STEM education. Further empirical support should also be provided to this largely qualitative research study that finds positive outcomes for the students participating in STSP. This might help to increase the number of students choosing STEM careers to fill the demands in Malaysia and also other nations.



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