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PROFESSIONALS BACK TO SCHOOL - AN ENGINEERING OUTREACH PROGRAMME: A CASE STUDY IN MALAYSIA

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Abstract

The introduction of engineering education in K-12 classrooms opens up a number of opportunities for STEM learning to support the acquisition of knowledge and skills related to science and mathematics subjects. Several initiatives, including outreach programmes, have been carried out to promote engineering subjects and professions. To supplement the existing Malaysian curricula, an outreach programme seems a viable solution to help improve the understanding and awareness of the importance of engineering among students. In this regard, an engineering outreach program called Professionals Back to School was carried out involving a group of 40 students with the participation of several engineering practitioners. Later all the participants were interviewed to elicit feedback on the programme. The findings of the interview showed that all the participants agreed that the outreach programme was beneficial, and a majority found it to be motivational. Given these positive findings, engineering outreach programmes are highly recommended to Malaysian secondary schools to help create interest among schoolchildren in STEM education and professions.

Keywords: Engineering education, Engineering professions, School children STEM education, Outreach programme.

1. Introduction

Education worldwide is facing a serious problem in the teaching and learning of STEM (Science, Technology, Engineering, and Mathematics) as the number of students taking the subject matter is dwindling precariously. A number of efforts have been introduced to enhance STEM learning, and one of these efforts was the introduction of engineering education in preschools, primary and secondary (K-12) schools [1]. Nonetheless, these efforts would be futile if the number of

students taking STEM subjects is low. Thus, the need to attract young learners' interest in and appreciation for STEM learning grows more and more imperative.

Engineering education is not only about exposing schoolchildren to engineering concepts and technologies, but it also emphasizes the acquisition of STEM fundamental knowledge and skills. In this regard, the introduction of engineering education in schools brings in a number of opportunities for STEM teaching and learning [2]. Moreover, engineering education helps create strong interest among school children to pursue STEM majors in colleges and universities, ultimately leading them to choose STEM-related careers, such as scientists and engineers.

The interest in engineering education must be cultivated among schoolchildren through efforts of teachers and school administrators in creating positive environments for students to embrace the concepts of engineering [3]. One such effort could focus on promoting a better understanding of the impact of engineering on humankind. Enhancing this understanding could be made more intense by exposing students to real life examples. Engineers who are well versed with engineering concepts and applications could help students learn and value the essence of engineering among the uninitiated students with greater influence. In essence, students would be more receptive to ideas or suggestions made by the practitioners as the latter have relevant expertise and experience. Ultimately, the interaction between students and practitioners would help the former become motivated to learn STEM-related subjects and to be engineers.

In the context of the Malaysian education system, many efforts have been put forward to promote STEM among students, but the outcomes of such efforts were not significant. Furthermore, the number of students choosing STEM-related programs in institutions of higher learning is declining, whereas the need for technical workforce is increasing [4]. Thus, these opposing trends entail new strategies to be implemented urgently in Malaysian schools to improve the current model of teaching and learning of STEM subjects.

The introduction of engineering education in Malaysian schools is still in its infancy. As anticipated, efforts to enhance engineering education in schools are scarce even though its benefits to the students, teachers, and other stakeholders are highly recognized. In contrast, the promotion and implementation of STEM in developed nations, such as the US, has been very successful. Thus, more efforts or initiatives need to be planned and carried out to enhance STEM learning in Malaysia. Against this backdrop, a program called Professionals Back to School was introduced in a school in the state of Perak, Malaysia to promote STEM and engineering professions to a group of secondary school students. The main objectives of this program were to expose the participants to the fundamental concepts of STEM, promoting engineering professions and appreciate the importance of engineering through hands on activities. The programme was funded by the Malaysian National Communication Commission of UNESCO, with the support of the Institution of Engineers, Malaysia. This program also involved a group of technical undergraduates of Sultan Idris Education University. In this program, professional engineers from various disciplines were engaged to expose the students to engineering concepts and career prospects in engineering disciplines. In addition, hands-on activities, which were facilitated by

the technical undergraduates, were carried out to help the students to apply relevant engineering principles that would further improve their understanding.

2. Engineering Education in Schools

In the first two decades of the 21st century, many developed and developing countries face many challenges as technical developments are taking place with an unprecedented rate. To cater to these developments, more technical workforce is needed to help nations move forward for greater success. In this regard, producing this type of workforce consisting of technically trained personnel, such as engineers, has become an imperative. Hence, relevant stakeholders, notably the government, should take appropriate measures to help produce such professionals to help nations achieve economic progress smoothly.

Many initiatives have been carried out all over the world to promote engineering professions to schoolchildren [5 - 6]. One of the initiatives is the introduction of engineering education in K-12 curriculum. In this respect, the US has carried out many efforts in promoting engineering education at K-12 level in schools. According to Katehi et al. [7], many engineering programs and curricula are offered in the US where approximately a million K-12 students have received formal engineering education in the classroom. In addition, Katehi et al. [7] also cited that several thousands of teachers have participated in training workshops to teach engineering related coursework.

The introduction of engineering education in schools acts as a catalyst for better and effective science and mathematics literacy among students in schools, which has been proven to be successful in the US [6]. This kind of success could and should be emulated by other countries to improve students' science and mathematics academic achievements. More importantly, through engineering education that involves many problem-solving activities, the learning science and mathematics could be made more efficacious as their concepts are applied and demonstrated sufficiently. The nature of engineering which amalgamating science and mathematics could improve students' understanding of the conceptual knowledge that underlies relevant scientific and mathematical principles, thus improving students' academic achievements in those subjects in school [8]. Through learning engineering, students would be able to engage in scientific inquiry to solve engineering-related problems, such as engineering design, and perform mathematical analysis and modeling to verify the design [8]. Such learning helps students to master appropriate scientific, mathematical, and engineering concepts. At the same time, it also enables the students to learn technology subjects efficaciously [9]. Arguably, the introduction of engineering in K-12 education could help improve students' understanding and performance in science, mathematics, and technology.

Likewise, the implementation of engineering education in schools has also increased the awareness of STEM, engineering professions, and other related STEM professions, among students at K-12 level [9]. This awareness would ultimately boost the interest among schoolchildren in pursuing engineering and other STEM-related careers in the future. Briefly, engineering education could act as a catalyst to spur the growth of STEM education in schools. Pressingly, STEM learning needs to be made more effective by making students inclined with strong motivation to learn the subject matter and assisting them to develop deep

understanding of engineering concepts and principles. To address these needs, many educators have attempted various approaches to help make students understand engineering concepts and create interest in engineering [6, 8]. Undertaking these initiatives have not been easy due to existing curricular frameworks that have a number of constraints, such as logistics, time, and expertise; thus, all efforts to improve current STEM learning have to be carried out within prevailing learning environments or contexts [10].

In the Malaysian context, one of the major challenges in introducing engineering education in schools is the current curriculum that is not flexible enough to accommodate emerging learning needs, unless the Ministry of Education allows such undertaking through tedious, slow, curricular review. Therefore, the alternative of introducing engineering education in schools is through outside classroom activities, and one such activity is the outreach program.

Ensuring an outreach program is effective entails the involvement of practitioners, particularly engineers and engineering or technical undergraduates. Their participation in an outreach program has a tremendous impact on the success of such an effort as they could help schoolchildren to develop the appropriate perspective or mindset with regard to STEM learning. Essentially, engineers and engineering students would be able to share their experiences and expertise with students more intimately, thus making the latter more appreciative of STEM learning and interested in pursuing engineering careers [11].

From the practical standpoint, the participation of engineers and undergraduates could also support teachers to learn the latest, emerging engineering applications, which the latter could explain to students during science and mathematics teaching. Overall, an outreach program could provide a viable platform - the starting point toward STEM professions in the future - to foster students' interest in STEM. Currently, the number of Malaysian students enrolling in STEM education is not encouraging, thus an outreach program would serve as one of the avenues to help improve the current situation [4].

3. STEM Education in Malaysia and Outreach Programme

According to Nordin [12], the number of Malaysian students enrolling in science stream (track) at the upper secondary level has decreased to only 29% of the total number of students, the number of which is far too low, below the number recommended by the Ministry of Education. In fact, Malaysia's Ministry of Education (MOE) has targeted the number of students enrolling in the science stream at the upper secondary level to be at 60% of the total number of students. Apparently, students are more inclined toward pursuing the arts discipline compared with the science discipline. Precariously, this low number of upper secondary science stream students would translate into low number of engineering undergraduates at institutions of higher learning, ultimately resulting in low number of future engineers. Kier et al. [13] cited that the interest in STEM reach its peak during middle school years.

The low number of students in science stream in schools signals that more efforts by the main stakeholders are needed to increase the number of students in science stream. Notably, efforts should focus on reaching out to students who lack

interest and enthusiasm in science and mathematics education. Ensuring that these efforts would be effective entails appropriate mechanisms that should be carried out involving young children, particularly of preschool age [14]. Furthermore, these efforts should be made more intense for students of middle-grade level as their interest in STEM-related careers peaks at this stage.

Teaching science and mathematics should be delivered in more efficient and interesting ways to help retain students' interest in STEM subjects and encourage them to pursue careers in STEM-related disciplines [15]. Thus, the current practice of teaching science and mathematics in Malaysian schools should extend beyond the scope of the subjects by including activities that inculcate design skills, problem solving skills, and creativity. Such effective activities to help nurture these skills could be undertaken by embedding engineering education with science and mathematics education.

The introduction of engineering education to Malaysian schoolchildren could bring many opportunities for effective STEM learning. Strong interest in STEM among young students would contribute directly toward the national development as they would opt for science stream at the upper secondary level. Subsequently, having more science stream students would result in more students pursuing STEM-related programs at the tertiary level. In the end, with more engineering or technical undergraduates, meeting the demand for technical and scientific professionals, such as engineers, would be manageable. Of late, more and more engineering professionals are needed to help Malaysia drive its economic engine as highlighted by Kieong [16] that projected that Malaysia needs approximately 200,000 graduate engineers by 2020.

Embedding engineering education in existing science and mathematics subjects or introducing engineering education as a subject in Malaysian schools would be a complicated process. Moreover, teachers need to be retrained in order to adopt and apply engineering concepts in their classrooms. Thus, viable approaches need to be explored to introduce engineering education in Malaysian schools, and one of these approaches could be an outreach program, with the participation of practicing engineers.

An engineering outreach program can be conducted through engaging, hands-on, and authentic activities. As suggested by Adams et al. [17], to make such an approach a successful endeavor, both cognitive and pedagogical aspects need to be taken into account. In essence, the outreach program should include activities that entail the application of engineering concepts and principles such as follows:

i. generate engineering ideas and act on them,

ii. discuss and reflect on those ideas amongst the participants,

iii. have an experienced facilitator to assist the participants to learn the underlying engineering principles.

Likewise, Brophy et al. [1] emphasizes that outreach programs are extremely essential to help increase the pool of talented young individuals who have a keen interest in pursuing technical professions, such as engineers. In such a program, the involvement of professional engineers plays an influential role in promoting the interest in engineering among students. Given their vast experience and expertise, the interaction between engineers and students in this program could wield greater

impact on students' motivation in, and understanding of, engineering. This attainment of enhanced motivation and comprehension is made possible as engineers could discuss or explain the subject matter more convincingly and clearly based on the real world, transcending the textbook approach.

4. Professionals Back to School

In line with the effort to facilitate the introduction of engineering education, the researchers organized an outreach program called Professional Back to School, with the support of the National Commission of UNESCO, Malaysia and the Institution of Engineers, Malaysia (IEM). In addition, a group of technical undergraduates from the Sultan Idris Education University, Malaysia were recruited as facilitators. The participants of the program consisted of 40 secondary school students from a school in the state of Perak, Malaysia, with the age range between 13 and 14 years old. This program was carried out for two consecutive days.

The main objectives of this outreach program were as follows:

i. To raise awareness of STEM among the participants

ii. To cultivate interest in and positive attitudes toward STEM through hands-on activities.

iii. To promote understanding of the importance of engineering and the role of engineers in everyday life.

The activities included in this outreach program followed the concepts as recommended by Adams et al. [17]. The program was divided into two main parts: (i) Talks by the engineers and (ii) Hands-on activities.

For the first part of the program, three speakers from the IEM presented their talks on the importance of STEM, engineering in daily life, and engineering professions. The participants were actively engaged in the talks where they asked many relevant questions related to STEM and engineering careers. More importantly, through the talks the practicing engineers managed to motivate the students to ask more probing questions regarding STEM concepts and instill greater interest in engineering professions. These positive outcomes were not surprising as the speakers were able to relate concepts to actual situations in real life.

The second part of the program focused on an engineering design activity in which the participants were required to build a miniature house by joining the mortise and tenon of wood pieces and other soft materials. This activity was carried out in a group consisting of five team members and facilitated by two technical undergraduates for each team. The main aim of this activity was to infuse the concepts of STEM by linking engineering design elements such as putting together the wood pieces and other materials in building a miniature house to mathematics and science involving the calculation of the stability and angle and the choice of the right material, respectively. The topics involved in this activity are as followings:

- Space (Mathematics)
- Stability (Science)
- Geometry (Mathematics)

The design process involving the construction of a miniature house exposed the participants to the appropriate approach to identify and solve engineering problems using scientific and mathematical knowledge. In essence, this process enabled the participants to experience the practical aspects pertaining to interconnection between science and mathematics in engineering design and the practicality of the conceptual knowledge of both science and mathematics, which they had learned in the classroom.

5. Methods

To test the effectiveness of the objectives of Professionals Back to School outreach program, an interview was carried out involving all the participants (20 males and 20 females) immediately after the completion of the program applying purposive sampling method. Three open ended questions were asked to the interviewees:

Q1: What is your opinion regarding the Professionals Back to School outreach program?

Q2: Did the program manage to raise a strong awareness of STEM? Please comment.

Q3: Did the program manage to promote a good understanding of engineering concepts and professions? Please comment.

The interviews were conducted in Malay language, the official language of Malaysia, and the interview transcripts were later translated into English for the purpose of reporting. All the questions were verified by three educators who were involved in the education and engineering education sectors to ensure the reliability of the questions.

For question Q1, the participants' answers or feedback were coded into two possible outcomes, namely *positive* and *negative*. For questions Q2 and Q3, their answers were coded into three possible outcomes, namely *agree, undecided*, and *disagree*.

6. Results and Discussion

The interview results have overall reached its saturation at the 11^{th} respondents (average) for each question asked in which it verifies the validity of this study.

The interview results of question Q1 indicated that all the respondents (100%) opined that the program was beneficial to them. For example, one of the female respondents succinctly expressed her thoughts as follows:

"This program has exposed me to STEM, especially engineering. I started to appreciate STEM and realized how important it is in my life."

Similarly, one male respondent stated positively as follows:

"I love this program because the involvement of engineers has really motivated me to appreciate engineering. I like the hands-on activities, which I did with my friends. I want to be an engineer when I grow up."

Evidently, the interviewees' positive responses reinforce the imperative of implementing outreach programs to help create awareness on STEM. In particular, organized talks or presentations by engineers, coupled with hands-on activities, would be able to act as a strong catalyst to spur strong interest in STEM and engineering professions among students.

For question Q2, 30 interviewees (75%) indicated that they became aware of the importance of STEM; in contrast, only 10 interviewees (25%) were undecided about the outcome of the program in creating awareness of STEM. For the positive feedback, a female interviewee stated her opinions revealingly as follows:

"Building the miniature house has provided me an opportunity to understand the concepts of STEM. The facilitators have guided me and my friends very well, and they have also inspired me to be like them one day."

On the other hand, one of the undecided male respondents declared quite negatively as follows:

"I enjoyed the activities of the program, but I could not decide whether the program has created awareness on STEM as I do not have much interest in science and mathematics in school"

Clearly, for the majority of the interviewees, the program did manage to raise a strong awareness of STEM. Particularly, the hands-on activities exerted a tremendous impact on the students' appreciation of STEM learning. Nonetheless, such enthusiasm was not shared by a small number of students, owing to their lack of interest in science and mathematics. Thus, educators should explore other strategies to invoke interest in STEM for this type of student.

For question Q3, its results replicate the results of question Q2 where 75% of the interviewees believed that they had gained greater understanding of engineering concepts and professions through the outreach program.

Among them, two interviewees (a female student and a male student) in unison summed up their positive thoughts eloquently as follows:

"Working in a team is a good way to accomplish the engineering design assignment effectively. At the same time, the activities have made all of us realize the importance of engineering in our daily lives. The engineers have motivated us to be like them, contributing to the wellbeing of the society."

In contrast, the remaining 25% of the interviewees were undecided about such an impact of the program. Their feedback was filled with signs of uncertainty as exemplified by a female interviewee's response as follows:

"I do not have much interest in STEM, therefore, I really could not decide whether I agree or not; but the talks and hands-on activities regarding engineering concepts and professions are a good start for me to appreciate the importance of engineering."

The positive findings based on questions Q2 and Q3 reinforces the importance of embedding science and mathematics education in engineering education in which the latter would allow students to learn the practical applications of the former. Thus, outreach programs, such as carried out in this study, could provide students with the opportunity to gain relevant engineering experience to enhance their scientific and mathematical knowledge from the practical standpoint.

Furthermore, such a program could also help create interest in engineering for students who are not keen on science and mathematics. Through such a program, talks by the practitioners and hands-on activities to enhance students' conceptual knowledge of science and mathematics would eventually lead students to develop interest in STEM - the impact of which would motivate them to choose STEM-related courses and professions in the future.

Table 1 illustrates the responses of the respondents on each question asked during the interview process.

Table 1. Responses of the respondents for Q1, Q2 and Q3.

Question No.	Responses
Q1	100% - programme was beneficial
Q2	75% - aware of the importance of STEM; 25% - undecided on the importance of STEM
Q3	75% - gained greater understanding of engineering concepts; 25% - undecided on the impact of the programme.

Overall, the designed engineering outreach program called Professionals Back to School had achieved its main objectives. The findings from the interview could be summarized as follows:

i. The involvement of practicing engineers and technical undergraduates in the outreach program has a positive impact on the participants' perception of its benefits. As STEM concepts were better explained, students became inspired to pursue studies in STEM-related courses.

ii. The teamwork and collaborative activities have motivated the participants to carry out the engineering design activity more effectively.

iii. The engineering outreach program has made the participants with low interest in science and mathematics more interested in STEM through design activity and engineering talks, which helped improve their understanding of engineering.

7. Conclusion

The designed engineering outreach program has achieved its objectives in promoting engineering concepts and technical professions, and creating awareness of STEM among the participants. The involvement of practicing engineers and engineering undergraduates enabled the participants to understand and appreciate the concepts of STEM and its related professions. From the motivational perspective, both the engineers and technical undergraduates became the source of inspiration to the participants. In addition, the outreach program encouraged the participants who lacked interest in science and mathematics to become more interested in STEM.

Thus, more efforts of this kind of programme are needed to expose students to engineering and its design activities in which the acquisition of a wide range of

knowledge and skills related to science and mathematics would be facilitated more effectively. In the long term, more students would be motivated and inclined to study STEM-related courses, which eventually helps increase the number of engineering undergraduates to meet the demand for highly skilled technical workforce of the future. At the same time, this study could be extended further by conducting longitudinal study to investigate the long term effect and sustainability of the STEM related outreach programme.

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