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Nurturing Engineering Enthusiasm and Soft Skills in High School Students*

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In this paper, we present a study of an educational program to nurture engineering enthusiasm among high school students. In this program, we designed a one-year project-based learning program focusing on microcontroller applications, where selected high school students (15 to 16 years old) were guided by mentors consisting of engineering undergraduate students. The participants of this study were trained with microcontroller know-how and on the development of specific soft skills through hands-on modules. The objective was to foster their enthusiasm in engineering and cultivate several soft skills, such as communication, teamwork and life-long learning, which are essential for students to become good engineers. The outcomes of this program demonstrate that the high school students have shown positive enthusiasm towards engineering and have improved their soft skills.

Keywords: engineering education; high school students, microcontroller; hands-on, mentoring; project-based learning (PBL)

1. Introduction

A pool of talent of exceptional engineers is essential to sustain rapid growth in national development. Quality engineers are typically being benchmarked, based on their strong technical skills, experience and possession of excellent soft skills such as communication, teamwork and life-long learning [1, 2]. The university has constantly played their role in attaining these traits by using many methodologies in education to transform students into quality engineers. However, to some students, engineering is seen as one of the difficult subjects due to the math and science involved in the learning process. More must be done to encourage high school students to select engineering as their preferred subject at university [3]. We believe this effort must be reach down to high school level where student teaching should be approached in an interesting way to increase student interest in engineering subjects, and hence choose engineering as their future career. Several programs have been reported to make engineering the career of choice, such as a freshmen seminar [4], precollege summer program [5–8] and a multifaceted outreach program based on a certain engineering subject [9]. Each of these was designed to expose and educate the high school students with professional development and technical activities related to the engineering field and profession. It is worth mentioning that most outreach programs that are accomplished in a single academy session will result in the minimum impermanent impact to the outlined objective. Pierson *et al.* in [5] has discussed this issue in detailed and explicitly mention the importance of having a continuous program and effort to instill a better understanding and interest in an engineering career. In this paper, we report a one-year engineering educational program, the "Microcontroller School Mentoring Project", where the main learning activities were based on microcontroller applications. This program is carried out in several sessions/phases over a year, so as to continuously promote engineering enthusiasm among high school students and inculcate them with appropriate soft skills to become better engineers in the future.

This program was initiated with several lecturers from the Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM), along with the industrial collaboration of United Engineers Malaysia (UEM). In general, it was a project-based learning (PBL) approach where high school students were first exposed to the basic microcontroller function and its applications. With selected engineering undergraduate students as their mentors to assist them, the high school students were then required to come up with an application with the theme "something that is beneficial to the community," using their knowledge of the microcontroller. The learning activities took place in groups, where each group comprised six to seven people: four high school students, two engineering undergraduate students and a lecturer, where they acted as member, mentor and advisor, respectively. The mentor played a major role to assist the high school students on technical know-

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how, whereas the lecturers were there to inform the whole learning process so that both parties (high school students and mentors) performed their roles effectively.

Forty students from two selected high schools, SMK Taman Nusa Jaya and SMK Kompleks Sultan Abu Bakar, were invited to participate in the program. They were chosen from fresh third-year high school students who had two years to go before sitting the Malaysia Certificate of Education exam (O-level equivalent). In connection with the objective, a series of activities were designed, most of which were performed in groups. In Section 2 of this paper, a detailed description of the program is presented. This includes a description of the activities for a one-year program, the methodology of the learning approaches and the list of projects proposed by the groups. Section 3 presents the program evaluations based on a quantitative survey and qualitative study carried out to the participants. Section 4 gives a discussion of the results, followed by a conclusion.

2. Description of the program

2.1 Program overview

We segregate the program into six phases as depicted in Table 1. The program was designed to accommodate the engineering learning process of the high school students, which involved the development of soft skills in a multidisciplinary area. It was also to accommodate the best time for high school students and engineering undergraduate students to meet and work together in a group. Each phase comprised five-day working activities where the location of the activity depended on the nature of the activities.

Preliminary Workshop (Phase I) was conducted in UKM where high school teachers and engineering students (mentors) were invited to have a brief introduction to the program objectives. Here, the designed hands-on modules were presented and feedback was taken from the participants to ensure that the level of technicality is suitable for high school students. Both parties were encouraged to get involved in the designed hands-on modules so that they had a better picture of what high school students would experience during the program. In Phase II, forty high school students were invited to UKM where another brief introduction to the program was given. They were first put into groups of four, with two engineering students engaged in each group as mentors. In the groups, the mentors facilitate the students to gain a basic understanding of the microcontroller and its applications. During the five-day activities, each group was asked to come up with a project that could be used in the community using the microcontroller. In this phase, the high school students were encouraged to come up with a simple project with the microcontroller as the heart of the application. They were facilitated by mentors to produce an innovative application using what they had learned in the modules. In order to attain the result, the mentors helped them in the decision making process such as data gathering, brainstorming, listing, deci-

Table 1. Microcontroller School Mentoring Project phase

Phase	Activity	Venue	Description
I	Preliminary Workshop	Microcontroller laboratory (university)	Selected high school teachers and mentors were briefed with the objectives, their roles and learning outcomes of the program. They were also being trained with the designed hands-on modules.
II	Microcontroller Workshop I	Microcontroller laboratory (university)	Selected high school students were given an introduction to the program. Groups comprising four high school students and two mentors were formed. Students had hands-on exposure and education with the microcontroller and its applications. Each group was then given the tasks of proposing a project (application using the microcontroller) and presenting their idea at the end of the session.
III	Microcontroller Workshop II	High school (SMK Taman Nusa Jaya and SMK Kompleks Sultan Abu Bakar)	Continuation of the second phase. The workshop resumed with more in-depth microcontroller training modules, such as code writing, compiling source code and troubleshooting. At this phase, discussions regarding the projects among groups were carried out in detail.
IV	Design and Development Workshop I	Microcontroller & mechanical laboratory (university)	Electrical parts and the mechanical framework were developed. This task was carried out with the assistance of technical staff.
V	Design and Development Workshop II	Microcontroller & mechanical laboratory (university)	Continuation of the fourth phase. In this phase, all groups were asked to complete their remaining task. At the end of the workshop, they were requested to present their prototype to other groups.
VI	Showcase	High school (SMK Taman Nusa Jaya)	A showcase was held in SMK Taman Nusa Jaya where all projects were presented to the public.

sion making, action and evaluation. Mini presentations to their colleagues were organized at the end of the activities.

Phase III was the continuation of the second phase where the high school students were equipped with more in-depth microcontroller training involving additional microcontroller modules, for instance, handling motors, Analog-to-Digital converters (ADC) and sensing inputs. In addition, students were exposed to structured learning with hands-on modules, starting with a basic knowledge of the microcontroller, programming and compiling source codes. Apart from that, the proposed projects were discussed in detailed to ensure that the working concept of the projects could be materialized. Technical staff from the university were invited to give advice in order to improve the design, especially the mechanical and electrical parts. At this stage, the student will learn how to explain their ideas and to improvise any changes to their proposed project in order to make it feasible.

The mechanical framework and electrical parts were developed in Phase IV. High school students were encouraged to participate in assembling the parts with the assistance of the technical staff. Phase V is the continuation of the fourth phase where all groups were required to fine-tune their project prototype. At the end of the activity, each group was required to demonstrate their work to their colleagues. Phase VI is the final stage of the program where high school students were requested to demonstrate their projects to the public in a showcase held at SMK Taman Nusa Jaya. At this stage, the accumulation of learning experience and cultivation of engineering enthusiasm was hoped to extend throughout the high schools students.

2.2 Learning activities

Several activities were planned throughout the program to promote interest in engineering learning and the development of soft skills. It is worth mentioning that organizing a one-year program involving two different institutional was very challenging. Each session needed to be pre-planned carefully so that the sessions were able to take place when all the parties are available. Concerns included the semester/school breaks, examination period, transportation, and the usability of the laboratories. Furthermore, the costs involved in the microcontroller workshop are relatively high, specifically those for transportation and the project's development (microcontroller kits and components required for each group).

2.2.1 Hands-on

In order to boost the learning process, the high school students were introduced to hands-on teaching modules. The modules were designed to give them a basic understanding of microcontroller concepts and its applications, including source code writing, compiling and programming. Examples of basic applications that were introduced were automatic water level adjustment control, a plant watering system, traffic lights, temperature and humidity controls and a line tracing robot., students were assisted by mentors in the learning process, and a hands-on manual was provided.

2.2.2 Project-based learning

Working in groups, students were given the task to come up with an innovative idea based on what they had acquired in the learning activity. This project-based learning (PBL) approach was chosen to promote their interest and creativity gained from the problem. It was also used to encourage the students to develop the targeted soft skills. Lifelong learning was one of the traits that was cultivated in the PBL. We would like to support the high school students with the concept of their ability to self-motivate in learning and attain knowledge informally. During their learning process, they were encouraged to seek knowledge other than that which they had learned in the modules. They were given the opportunity to look for information via the internet, the library and any other means. They were also encouraged to make an informal visit to the place that they would like to implement their project.

2.2.3 Mentoring

The learning activities of the high school students were facilitated by the engineering undergraduate students who acted as their mentors. The mentors were required to train high school students using the hands-on modules and facilitate them in the decision making process (gathering information, brainstorming ideas, listing solutions and deciding the best solution for the application). Also, the mentors have to administer the whole development of the project so that it was feasible, deliverable on time and within their capability.

2.2.4 Multidisciplinary exposure

The high school students were exposed to a multidisciplinary field as they progress to complete their project. Additional training, such as electrical wiring, soldering, mechanical assembly, budgeting and troubleshooting were completed during the phases. Nevertheless, some of the activities required the assistance of the technical staff, where they were encouraged to involve themselves under the staff supervision.

2.2.5 Technical presentation

Throughout the program, the high school students were helped to improve their soft skills development. Beginning with Phase I, they were encouraged to demonstrate their confidence and communication skills by giving a technical presentation. This exercise was carried out in several phases in order to improve their skills. They were also being taught to use standard presentation aids such as Microsoft Power Point.

2.3 List of projects and the description

At the end of the program, ten projects were presented by the students.

2.3.1 Auto-shield

The principle of the project was to develop an automatic controlled curtain that responded to the change of heat and brightness. The idea was to automatically close the curtain depending on the weather by using a microcontroller. Basically, a Light Dependent Resistor (LDR) and thermistor were operated as sensors to detect changes in the surrounding condition. A motor was applied to open and close the curtain.

2.3.2 i-itik

The basic idea for this project was to design a small-scale duck farming management system that can automatically operate the supply of food, drink and heat. A microcontroller was designed to provide the necessities according to a schedule and constantly maintain the amount of heat, water and pest-free conditions in the farm. In principle, timer, thermistor, level sensor and high frequency devices were operated to manage schedule, heat, water supply and pest control, respectively. It is worth mentioning that this project has successfully been carried out at one of the duck farms owned by one of the group member's father.

2.3.3 i-ampaian

i-ampaian was a simple idea that came out of the group. It was designed to be an 'intelligent cloth dryer' that was able to move the clothes into a shaded area if it senses difficult weather circumstances, such as cloud, rain and extreme heat. This invention works by simply sensing the brightness and heat of the surroundings. The main sensing components used in this project were a thermistor, humidity sensor and LDR.

2.3.4 Automatic queued gate

This project is designed to create an automatic gate to manage overcrowding in purchasing canteen food. The idea was to allow a certain number of students to go through the gate while the others wait their turn. The main sensing device involved was an Infrared (IR) transceiver.

2.3.5 K.K. walk through

This project is designed to accommodate an efficient and comfortable method of purchasing items in the school mini store during peak hours (short recess interval). The concept is similar to a typical drive through service in a fast food restaurant. Students just need to key in the purchasing items and the total amount will be displayed immediately along with the required item. The main components involved were a numeric keypad and Liquid Crystal Display (LCD) display.

2.3.6 Cyber, Smart, Stick (CS^2)

This designed is invented to assist a visually impaired person with an innovative smart cane. An ultrasonic sensor is attached to the customized stick to give them better notification of the surroundings and a buzzer will produce a sound that can alarm the disabled person and other people. The stick is made of a lightweight material (aluminum) and is easy to hold.

3. Program assessment

There are two main objectives for this program: (i) nurturing engineering enthusiasm and (ii) promoting the soft skills of the high school students. The first objective can be measured by evaluating the students' perception towards the engineering profession, choosing engineering as an essential program at university and considering a future career as an engineer. The second objective evaluates their interpersonal skills that were developed throughout the program such as communication skill, confidence, teamwork and life-long learning. Both quantitative and qualitative assessments were carried out after the program to determine whether these objectives were successfully met.

Assessments are made from the feedback given by the participants from the given questionnaire form and recorded video from an interview session with the participants. The video serves as evidence to support the finding from the questionnaire form. The questionnaire consists of five (5) different components, as summarized in Table 2 and evaluated based on the Likert scale ranges from scale '1' (strongly disagree) to '5' (strongly agree). It can be observed that the teamwork skills component achieved the highest mean score (3.99), while the mean score on their perception towards engineering career is the lowest (3.74). Anyhow, it can be seen that all of the evaluated components have a mean

Table 2. Microcontroller school mentoring project phase

No.	Assessment	No. of questions	Mean score	Variance
1	Perception of engineering profession	3	3.74	0.59
2	Communication skills	3	3.77	0.55
3	Teamwork skills	3	3.99	0.60
4	Self-confidence	3	3.95	0.53
5	Life-long learning	3	3.93	0.53
	Overall (average)	15	3.88	0.56

score closer towards the level of 'Agreement' from the Likert scale.

Table 3 summarized the quantitative analysis from the questionnaire. For perception in engineering profession evaluation, a majority of 22 participants (54.7%) likely 'Agree' that the engineering field is an interesting profession (mean score of 4.02). This finding suggests that the students participated in the microcontroller mentoring project demonstrated a high level of confidence to choose engineering as their future profession. However, they least 'Agree' (mean score of 3.57) that the hands-on approaches taken in the microcontroller program could help them to build an interest in the engineering industry. However, the majority of the participants are 'Undecided' (22 participants, 52.4%) about whether the microcontroller hands-on approach had helped them to increase their interest in the engineering discipline. This finding contradicts the result from the life-long learning component, in which the highest level of agreement (mean score: 4.33) comes from the following question:

> "I like to be involved in activities to learn something through experience."

Although the students exhibit the highest level of agreement for this question, it can be deduced that the hands-on activities are not the dominant factor in influencing their interest in the engineering discipline. This can be supported from the second assessment, whereby only four (4) students, i.e. 9.5% from the population, show the highest level of agreement when asked whether the hands-on approach helped to boost their confidence in an engineering career.

Table 3. Participants level of agreement for the evaluated components

No	Assessment	Strongly disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly agree (%)	Mean
Part 1: Student perception towards engineering discipline							
1	Engineering is an interesting discipline.	0 (0.0)	0 (0.0)	9 (21.5)	23 (54.7)	10 (23.8)	4.02
2	Hands-on approaches help to increase my interest in engineering.	0 (0.0)	0 (0.0)	22 (52.4)	16 (38.1)	4 (9.5)	3.57
3	Guidance from the lecturers help to increase my interest in engineering.	0 (0.0)	2 (4.8)	21 (50.0)	10 (23.8)	9 (21.4)	3.62
Part 2: Communication skills							
4	I always listen and understand first before replying to queries from a friend.	0 (0.0)	0 (0.0)	16 (38.1)	22 (52.4)	4 (9.5)	3.71
5	I accept and respond positively towards feedback given to me.	0 (0.0)	1 (2.4)	11 (26.2)	27 (64.3)	3 (7.1)	3.76
6	When I present something, I try my very best to make my audience understand the contents of the presentation.	1 (2.4)	2 (4.8)	10 (23.8)	19 (45.2)	10 (23.8)	3.83
Part 3: Teamwork skills							
7	I always offer help and provide information to my group.	0 (0.0)	0 (0.0)	14 (33.3)	22 (52.4)	6 (14.3)	3.81
8	I am aware of my role in the group.	0 (0.0)	1 (2.4)	5 (11.8)	23 (54.8)	13 (31.0)	4.14
9	I understand how collective efforts can be more productive than individual effort alone.	1 (2.4)	0 (0.0)	10 (23.8)	17 (40.5)	14 (33.3)	4.02
Part 4: Self-esteem							
10	I always believe in myself.	0 (0.0)	0 (0.0)	11 (26.2)	23 (54.8)	8 (19.0)	3.93
11	I have clear objectives in my life.	0 (0.0)	0 (0.0)	8 (19.0)	17 (40.5)	17 (40.5)	4.21
12	I always believe in my ideas and want to share with others.	0 (0.0)	0 (0.0)	17 (40.5)	20 (47.6)	5 (11.9)	3.71
Part 5: Life-long learning skills							
13	I love learning activities.	0 (0.0)	0 (0.0)	10 (23.8)	22 (52.4)	10 (23.8)	4.00
14	I like to be involved and to learn something in activities through experience.	0 (0.0)	0 (0.0)	2 (4.8)	24 (57.1)	16 (38.1)	4.33
15	I often read the additional material, such as magazines and books to understand something.	0 (0.0)	2 (4.8)	20 (47.6)	19 (45.2)	1 (2.4)	3.45

It is also observed that the students have the lowest mean score of 3.45, where the majority of the 20 participants have a partial opinion related to supplementary reading material, whether it helps to improve their life-long learning experience or not. This finding shows the participants' level of dependency on the supplied learning materials or classroom delivery methods.

For the assessment of the teamwork skills, it is apparent that the participants are aware of their role in the group (mean score of 4.14). From the video interview (time interval: 02:44–04:01), one of the participants highlighted that the role of teamwork became the dominant factor, rather than the roles of the lecturer:

> "Our team members can solve the design problem from exchange of opinions and trial-and-error approach, with some assistance from our lecturer."

The above statement agrees well with the result from the third assessment, in which the participants have a neutral opinion (majority of 50%) related to the roles of guidance from the lecturers in the microcontroller program. On the positive side, the statement expresses the participants' level of agreement on the impact of a collective effort from a team to achieve a specific goal (mean score of 4.02). The results from the teamwork skills component can be supported by another interview session with one of the participants (time interval 01:55–02:29), who had been transferred to the other school, but was willing to travel from his current location to complete the remaining tasks on the project:

> "The spirit of teamwork that has been established since the beginning of this project has encouraged me to complete the remaining part of this challenging project."

However, they demonstrate lower level of agreement when asked about the benefit of sharing information within the group (mean score of 3.81), where the total of 14 (33.3%) students 'Undecided' and only 6 (14.3%) students 'Strongly agree' with that statement. This finding can be associated with the self-esteem component, where a total of 17 (40.5%) students 'Undecided' to share their ideas with others. In other word, both of the results indicate that the students display a mild tendency to develop an individualistic character, whereby they are uncertain when entrusting others with their valuable information or ideas. On the other hand, the highest mean score comes from the self-esteem attribute, where the majority of 17 (40.5%) students 'Strongly agree' that they have a clear objective about their life.

In general, it can be summarized that the quantitative analysis has shown that the microcontroller program has fulfilled the two objectives from the overall mean score (3.88), i.e. high level of 'Agreement' (near to the Likert scale of 4), whereby the mentoring programs have enhanced their interest towards the engineering profession, while improving their interpersonal skills. Our next research direction aims to analyze the perspective of the participants who have recently enrolled for the second intake. The study involves experimental analysis on the program's approach. The results will be compared against the first participants involved in this research. In addition, the mentor's perspective will be investigated to evaluate their engineering learning development and soft-skill competencies.

4. Conclusions and recommendations

An effort to foster engineering enthusiasm in the high school students and thus promote it as their future career has been demonstrated in this one year, multi sessions' program. Each program was designed to instill a continuous awareness and understanding towards engineering. We have chosen microcontroller applications as the engineering learning subject to stimulate the students' interest using the designed hands-on modules. Proper guidance has been carried out in groups by dedicated engineering undergraduate students and lecturers. The high school students were also exposed to learning activities that cultivated the soft skills needed to become excellent engineers. The research findings show that the high school students were very receptive and enjoyed participating in the new approach to engineering learning. They have a fresh paradigm and interest in engineering subjects and hence an increased interest in the field of engineering. This was supported by the evaluation analysis that was carried out on the high school students during the program. The findings also show that the program has improved their soft skills in terms of ability in making technical presentations; they were more confident, and gained good teamwork and life-long learning, which are among the finest traits in becoming exceptional engineers.

In conclusion, the microcontroller program has given the department a different outlook on the characters and essential soft skills of an engineering graduate from the perspective of the high school students. Based on the results analysis and positive feedback from stakeholders, a continuation of the program is highly recommended. However, a slight improvement has to be carried out in terms of the program's schedule, the hands-on module, the well-documented guidelines to mentor and more interactive delivery methods to the high school students. To ensure sustainability of the microcontroller program, we suggest the following: (i) motivate the undergraduate students to maintain their commitment in the microcontroller program by justifying their work and effort with notional credit spends in undergraduate co-curriculum activity/project (learning contract), (ii) initiate invention/engineering club at the high schools.

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