The effectiveness of STEM mentoring program in promoting interest towards STEM

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Abstract. STEM mentoring program were introduced in order to overcome the declining interest in STEM subjects in schools. This study aims to measure the effectiveness of STEM mentoring programs on the students’ interest towards STEM. Comparisons between girls and boys on their interest towards STEM were also conducted. The STEM Mentoring programs in this study consisted of an array of the program from various faculties namely (i) BITARA STEM and STEM Career Interest from Faculty of Education (FPEND), (ii) CRYSTAL from Faculty of Engineering and Built Environment (FKAB), and (iii) Science Camp and SEE Nature from the Faculty of Science and Technology (FST). This study used post-test control group design involved 198 students in one of the states in Malaysia. Data garnered from the study was described by means of descriptive analysis, which later followed by inferential analysis using independent sample t-test. Overall, the findings revealed that there is significant difference between girls in treatment group in interest towards mathematics. This study showed that research should be done more thoroughly on mentoring program, need to find out the suitable framework in implementing STEM mentoring programs and possible implementation of Blended Mentor Mentee programs for further research to get a corroborative evidence.

1. Introduction
Interest in science and mathematics learning among school students is declining worldwide including Malaysia [1-3]. Reasons for the decline include learning in silo and not integrated, unable to see the relevance of science and mathematics in everyday situation, subject matter too difficult and career is uninteresting [4]. One of the ways to address this phenomenon is by promoting STEM education in that STEM integrated education brings real world problems and contexts into schools. At the same time, [5] argued that another underlying issue to the decline, which has not been addressed, is concerned with the students’ own identity to the discipline- i.e. unwillingness to opt for science relate studies and careers. Both the pedagogical and psychosocial factors could be addressed through a mentoring system between STEM higher education (HE) students (commonly known as facilitators) and school students. Often courses in higher education involve integration of more than one discipline and deal with complex and real world problems. STEM facilitators serve as role models are able to project positive STEM identity - such as projecting images whereby STEM researchers and their work is actually helping the community e.g. Device methods to overcome famine or engineers develop method to produce alternative energy sources with less pollution consequences. While mentoring is seen important, the effectiveness of mentoring program varies in results and effect size. Traditional face to face program is better than online mentoring and vice versa [6]. The fact that mentoring studies lack of treatment group which is a limitation of any mentoring program [6]. Thus, this study addresses the problem of declining interest in science and mathematics and promoting positive STEM identity.
through mentoring system. In addition, this study determines the effectiveness of the program by using a post-test control design approach.

1.1. Mentoring system
Improving the state of science education in Malaysia has become a national priority. In the USA, one response to this problem has been the implementation of STEM outreach programs designed to reignite the interest and awareness of students and parents with the aim to increase the number of students that enter graduate programs in STEM at school and tertiary levels [7]. Studies such as [8] showed that outreach programs in Malaysia, which are gaining in numbers and participations from industries, universities and NGOs, are able to excite and engage students in STEM and students are also able to develop the STEM knowledge and skills. The common underlying thread in outreach or enrichment programs (e.g. robotic clubs, science camps, STEM camps) by STEM graduates and academia is the mentoring process between a mentor and mentee during and after the program. Research shows that students are inspired to involve in STEM when they see the relevance in STEM namely impact of STEM research in the improvement the world that they associate with [5].

Research suggests providing access to faculty mentoring through enrichment programs may also increase the degree to which students identify themselves as scientists [9]. In a review of the impact of afterschool programs, [1] found that university students’ current interest in STEM is associated with their participation in afterschool programs. They also argued that students with average achievement in science and mathematics but with an early interest in pursuing STEM fields at a higher level is a better predictor compared to those who are high achievers but do not show interest in the same careers. Thus, mentoring could create a positive STEM identity that leads to better predictor for the student to pursue STEM fields in the future. Mentoring is a relationship between a less experienced individual, called a mentee or protégé and a more experienced individual known as the mentor [10]. Various models of mentorships exist- the more traditional ones such as dyadic, face-to-face, long-term connection, including those at the opposite end of the spectrum-short term and exclusively electronic. Mentors support their mentees in setting appropriate and challenging goals. They motivate mentees for STEM activities and increase their interest in STEM topics through conversations and learning activities [6]. STEM mentoring leads to greater STEM achievement than their counterparts who lacked such opportunities. At the same time, face to face mentoring program such as internship where students learn through immersion in the authentic environment is also meaningful to students socially and intellectually [11], especially those from rural schools who might not have access to internet. Aspects of effective mentoring is also essential. [10] suggest based on literature that with mentors should provide (1) psychological or emotional support, (2) a role model, (3) assistance in goal setting and career paths, and (4) subject-specific expertise. Thus, mentors provide psychosocial and academic support. Psychosocial support is most closely linked to identity formation.

The STEM mentoring programs in UKM has been provided outreach programs since 2013. Thus, one can assume that the programs are equipped with experienced facilitators. Some programs such as BITARA STEM conduct training of trainers’ program for their own facilitators so that a more effective mentoring process is provided to the schools. The STEM Mentoring Program was design based on the multidisciplinary STEM activities from three faculties in UKM. The scope of the activities in the program varies from learning embedded system engineering, the nature, insect studies and chemical processes. The hands-on activities gave participants the opportunities to touch and knowledge and products. Such activities aim to create an understanding and awareness that multidisciplinary STEM have an impact on students’ everyday life and industrialist in the future.

1.2. Objectives and research questions of the study
The objectives of this study were to assess the impact of students’ interest towards STEM through multidiscipline STEM projects in mentoring STEM program. The research questions were:
What is the level of students’ interest towards STEM after they were involved in STEM mentoring program?
Was there any significant different of interest towards STEM between groups (participated and non-participated in STEM mentoring program)?
Was there any significant interaction of interest towards STEM between groups and gender?

2. Research design
Posttest-Only Design with Non-equivalent Groups was used in this study. Based on this type of design, both groups (control and treatment) were only given post-test on a range knowledge of STEM and interests towards STEM.

3. Method

3.1. STEM mentoring program
UKM STEM mentoring program comprised of an array of STEM based programs namely CRYSTAL, See Nature, STEM Career, BITARA STEM and Science Camp (See Table 1). These programs are common in terms of: (a) types of activities- which are hands-on, (b) outside of the classrooms, (c) application of STEM knowledge, and (d) related to formal school curriculum. Most programs were conducted in one day at respective schools.

| Programs    | Modules          | Example of activities                          |
|-------------|------------------|-----------------------------------------------|
| CRYSTAL     | SCRATCH          | Create animation and character using SCRATCH software. |
| See Nature  | Forest, Insect,  | Students seek insects in their surroundings.   |
|             | Bird, Fireflies  | Study the structure and morphology of the insects. |
|             | Nature documentation | Shared their findings                        |
| BITARA STEM | Energy, Transportation, Wireless Communication, Urban infrastructure | Developing mini SMART communities |
| STEM Career | Career personality | Explore students profile of STEM career          |
| Science Camp| Energy, Transportation, Wireless communication, Urban infrastructure | Develop mini SMART communities                  |

3.2. Participants
A total of 400 students (mentee) from six secondary schools in Selangor district, Malaysia participated in STEM mentoring program. 25% from the total of mentees were randomly selected as a treatment group (N = 99). Non-participants in the STEM mentoring program from the same schools were randomly selected as a control group (N = 99). In addition, lecturers as a mentor (N = 20) and graduate students as a facilitator (N = 70) from three faculties (Faculty of Education, Faculty of Science and Technology and Faculty of Engineering & Built Environment) in UKM also participated in this program.
3.3. Instrument and procedure
A set of questionnaire of interest towards STEM was used in this research and employed 5-point agreement of Likert type response (1= strongly not agree to 5= strongly agree). The instrument was adapted from [13] which takes into consideration three main interests of STEM namely: (i) interest towards science, (ii) interest towards mathematics, and (iii) interest towards science & technology. This instrument has been verified by experts in term of construct and content validation. The reliability of the instrument from the pilot study indicates high Cronbach’s Alpha value for all constructs (Cronbach alpha > 0.07) (See Table 2). This instrument (post-test) then was distributed to the participants (control and treatment group) after the mentoring program ends.

Table 2. Items and Cronbach alpha value for interest towards STEM.

| Element                      | Cronbach alpha | Example of items                                      | Number of items |
|------------------------------|----------------|-------------------------------------------------------|-----------------|
| Interest towards science     | 0.733          | - I enjoyed learning science                          | 4               |
|                              |                | - I love doing challenging science activities         |                 |
| Interest towards mathematics | 0.910          | - I enjoyed learning mathematics                       | 4               |
|                              |                | - I love solving difficult mathematical problem       |                 |
| Interest towards engineering | 0.815          | - I love designing product activities                 | 7               |
| & technology                 |                | - I am interested to find out how the machine works   |                 |
| Interest towards STEM        | 0.854          |                                                       | 17              |

3.4. Data analysis
The data that have been collected from the post-test was analysed using SPSS 2.10 at the significant level p < 0.05. The analysis involved statistic descriptive to determine the level of interest towards STEM using the mean score and standard deviation. Meanwhile, inferential analysis involves MANOVA and independent sample t-test were used to identify the significant difference and interaction between group (control and treatment) and gender.

4. Result and discussion
4.1. Level of interest towards STEM
Table 3 shows the mean score and standard deviation value following by the level of interest towards STEM. The table indicates, the level of all three aspects of interest towards STEM are moderately high and high with the mean scores between 3.5 to 4.3. The interpretation of the level of the mean score was based on [14]. The level of the interest towards science is ‘high’ for both group and gender. This high score mean of interest towards science probably because in the early ages of learning, in this context were form one student (age 13 years old), the students have more desire or interest to know more about science. But it is feared that their interest in science decreases as their education level increases [15,16]. The current issues that showed interest towards science among school students is declining worldwide [1-3]. Hence, research have suggested [7,9], access of mentoring as an enrichment program or afterschool program can help to increase and maintain their interest.

Meanwhile, the level of interest towards mathematics indicated the different of level in both group and gender. Boys in treatment group shows moderate level of interest towards mathematics compared to the boys in control group with high level of interest towards mathematics. This finding could not be clarified further. It may be explain clearly if the pre-test was conducted as well as a qualitative study to learn more about the cause. On the contrary, girls in the treatment group indicate high level of interest towards mathematics compared to the girls in control group. Some research shows girls interest towards mathematics declined starting in the middle school [17] and worldwide including Malaysia [1-3]. However, one possibility which is contributing to increase the interest among girls is the usability.
of mentoring group approach [18]. It is shows that mentoring help students to hinder from losing interest towards mathematics and provide them with the scaffold they need to develop greater interest [6].

Based on the Table 3, interest toward engineering and technology indicate boys in the treatment group shows higher interest compared to the girls and control group. One possible reason for the low level interest among girls compared to boys is that that engineering and technology are stereotyped linked to a masculine field and machines are related to the quality valuable for boys compared to girls [19]. However, both girls and boys in the treatment group shows higher score mean compared to the control group. The mentoring programs which involved hands-on activities and multidisciplinary STEM project in creating product, together with the support and motivation form the facilitator, may help both girls and boys to cope with the challenge in accomplished their goals of projects.

Overall, boys and girls in the treatment group shows higher level of interest towards STEM compared to control group. The finding of this study does support previous finding on the positive effect of the STEM Mentoring programs on students' interest towards STEM subject [8]. Findings showed that students’ current interest in STEM is associated with their participation in afterschool programs [7]. STEM mentoring leads to a better STEM achievement than their peers who lacked such opportunities. Besides, according to [11], involving in face to face mentoring program is also meaningful to students socially and intellectually.

### Table 3. Level of interest towards STEM.

| Element                      | Group     | Gender | Mean score | Standard deviation | Level    |
|------------------------------|-----------|--------|------------|--------------------|---------|
| Interest towards Science     | Control   | Boys   | 4.129      | 0.646              | High    |
|                              |           | Girls  | 4.214      | 0.595              | High    |
| Treatment                    | Boys      | 4.250  | 0.490      | High               |
|                              | Girls     | 4.388  | 0.433      | High               |
| Interest towards mathematics | Control   | Boys   | 4.000      | 0.756              | High    |
|                              |           | Girls  | 3.620      | 1.055              | Moderate high |
| Treatment                    | Boys      | 3.885  | 0.956      | Moderate high      |
|                              | Girls     | 4.108  | 0.826      | High               |
| Interest towards engineering & technology | Control   | Boys   | 3.961      | 0.637              | Moderate high |
|                              |           | Girls  | 3.538      | 0.631              | Moderate high |
| Treatment                    | Boys      | 4.004  | 0.689      | High               |
|                              | Girls     | 3.743  | 0.620      | Moderate high      |
| Interest towards STEM        | Control   | Boys   | 4.030      | 0.496              | High    |
|                              |           | Girls  | 3.791      | 0.614              | Moderate high |
| Treatment                    | Boys      | 4.046  | 0.492      | High               |
|                              | Girls     | 4.080  | 0.451      | High               |

Mean score interpretation [14]:
1.00 - 1.99 (low)
2.00 - 2.99 (moderate low)
3.00 - 3.99 (moderate high)
4.00 - 5.00 (high)

4.2. Different and interaction between group and gender
Table 4 shows there are no significant group effect on the three elements of interest in STEM: interest towards science, interest towards mathematics and interest towards engineering and technology. Whereas, the main effect of gender is significant only for element interest towards engineering & technology, F (3,194) = 8.504, p < 0.05; Pillai's Trace = 0.118; partial η² = 0.118. However, only boys
showed the ‘significant’ effect from ‘moderately high’ to ‘high’ as the girls only showed slightly significant different of mean score (refer Table 3). While the effect of interaction between group and gender was significant only for element interest towards mathematic, $F(3, 194) = 1.724, p = 0.163$; Pillai’s Trace = 0.026; partial $\eta^2 = 0.026$.

**Table 4. Multivariate test.**

| Source    | Element | Sum of square | df | Mean square | F       | Sig. | Partial eta squared |
|-----------|---------|---------------|----|-------------|---------|------|---------------------|
| Group     | Science | 0.950         | 1  | 0.950       | 3.278   | 0.072| 0.017               |
|           | Math    | 1.527         | 1  | 1.527       | 1.768   | 0.185| 0.009               |
|           | E & T   | 0.673         | 1  | 0.673       | 1.639   | 0.202| 0.008               |
| Gender    | Science | 0.540         | 1  | 0.540       | 1.863   | 0.174| 0.010               |
|           | Math    | 0.269         | 1  | 0.269       | 0.031   | 0.577| 0.002               |
|           | E & T   | 5.127         | 1  | 5.127       | 12.491  | 0.001| 0.061               |
| Group*gender | Science | 0.031         | 1  | 0.031       | 0.106   | 0.745| 0.001               |
|           | Math    | 3.999         | 1  | 3.999       | 4.629   | 0.033| 0.023               |
|           | E & T   | 0.288         | 1  | 0.288       | 0.701   | 0.403| 0.004               |

Based on the results of the independent sample t-test as shown in Table 5 and Table 6 it was found that there was a significant difference between girls for interest in mathematics in control and treatment group ($t = -2.897, df = 127, p = 0.004$). Mean score of interest towards mathematics for girls in treatment groups is higher compared to girls in control group (treatment: mean=4.108; control: mean=3.620. (Refer Table 3).

**Table 5. Independent sample t-test by group.**

| Element       | Group   | Gender | Mean   | Standard deviation | t     | df  | Sig.  |
|---------------|---------|--------|--------|--------------------|-------|-----|-------|
| Interest towards mathematics | Control | Boys   | 4.000  | 0.756              | 1.759 | 97  | 0.082 |
|               |         | Girls  | 3.620  | 1.055              |       |     |       |
|               | Treatment | Boys  | 3.885  | 0.956              | -1.237| 97  | 0.219 |
|               |         | Girls  | 4.108  | 0.826              |       |     |       |

**Table 6. Independent sample t-test by gender.**

| Element       | Group   | Gender | Mean   | Standard deviation | t     | df  | Sig.  |
|---------------|---------|--------|--------|--------------------|-------|-----|-------|
| Interest towards mathematics | Boys   | Control | 4.000  | 0.756              | 0.537 | 66  | 0.593 |
|               |         | Treatment | 3.885  | 0.956              |       |     |       |
|               | Girls   | Control | 3.620  | 1.055              | -2.897| 127 | 0.004 |
|               |         | Treatment | 4.108  | 0.826              |       |     |       |

Based on the findings above, UKM STEM mentoring program is effective in improving interest towards mathematics especially for girls (see Table 6). This finding shows, negative stereotype with maths [19] or interest declined among girls can be overcome through STEM mentoring program with multidisciplinary STEM project. This mentoring program offers psychology and academic support by trained and experienced facilitators from different faculties. Because of this factor, therefore, the process of mentoring becomes effective [12].
5. Conclusion
UKM STEM mentoring program was conducted to explore students’ interest towards science, mathematics and engineering and technology. Participants consists of mentees (N=198), mentors and facilitators. The descriptive analysis showed that the level of the interest towards science is ‘high’ for both group and gender. Meanwhile, the inferential analysis showed that there was a significant difference between girls for interest in mathematics in control and treatment group. However, there were no significant group effect on the three elements of interest in STEM; interest towards science, interest towards mathematics and interest towards engineering and technology. The study indicated that the program was effective at modifying students; interest level as the result revealed positives changes for both group and gender but the data still not enough to suggest that the positive changes due to the interaction in this STEM mentoring program. Nevertheless, students who participate in a mentoring program tend to be more satisfied with their academic experience than their non-mentored peers [20,7]. The limitation of the study that there was no pre-test data thus future research should include a pre-post-test controlled design. In addition, followed up interviews would illuminate the effects of mentoring.

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