

Evaluation of Scratch Programming Mentoring Program amongst Primary School Students

Noorfazila Kamal^a, Mohd Faisal Ibrahim^b, Aqilah Baseri Huddin^c,
^{a,b,c}Integrated Systems Engineering and Advanced Technologies (INTEGRA),
Faculty of Engineering & Built Environment, UKM Bangi, 43650,
MALAYSIA,

Science, Technology, Engineering and Mathematics (STEM) education is an important agenda for the Ministry of Education Malaysia. Malaysia needs more STEM graduates to meet IR4.0 technology requirements. However, the declining enrolment of students in STEM is alarming. Various initiatives have been undertaken by the ministry to address this problem. One of the initiatives is a mentoring programme, where higher education institutions students act as mentors to school students. In this article, an evaluation of a mentoring programme in Scratch programming amongst primary school students is presented. Programming is one of the important skills in IR4.0 technology. Two important components in programming are logical thinking and programming language. This programme emphasizes the logical thinking aspect rather than programming language. A total of 40 primary school students consisting of standard 5 and 6 students participated in the program as mentees and 16 undergraduate students participated as mentors. The programme consists of two activities, namely training and a project. The students' knowledge is assessed after the training and project activity. Two types of instruments are used in this study which is a quiz and a presentation rubric. Based on the marks, statistical analysis has been conducted. The results show that the Scratch programming mentoring programme was successful in introducing and teaching students the skills of programming. A significant improvement in their knowledge can be seen after students have completed the project.

Key words: *STEM, programming, Scratch, mentoring, training, project.*

Introduction

STEM or Science, Technology, Engineering and Mathematics education is a priority in Malaysia. The STEM initiative in the Malaysia Education Blueprint 2013-2015 aims to prepare students with the skills to meet the science and technology challenges, and to ensure Malaysia has a sufficient number of qualified STEM graduates (Ministry of Education of Malaysia, 2013). The Malaysian policy target is to have a ratio of 60:40 for the number of students enrolling for STEM and non-STEM (Nasa & Anwar, 2016; Andrew, 2017). Unfortunately, the number of students taking up STEM subjects had dropped from 48% in 2012 to 44% in 2018. This is due to several factors such as limited and outdated infrastructure, perceived difficulty of STEM and inconsistent quality of teaching and learning (Ministry of Education of Malaysia, 2013). To overcome these problems, the government has introduced a new curricula which include higher order thinking skills, are project-based and ICT games-based. However, it is difficult to be implemented in school especially primary school as no learning kits and modules are available.

According to a survey by the Energy, Science, Technology, Environment and Climate Change Ministry (MESTECC), nearly 70% of students said they had low interest in STEM subjects because the teaching was too theoretical (Mustafa, 2019). Therefore, the Education Ministry Malaysia (MoE) has introduced the STEM for All (STEM4ALL) initiative to shift three current policies. The three policies are to increase student interest in STEM, to expand access to learning STEM subjects and to evolve STEM to STREAM (Science, Technology, Reading, Arts and Mathematics).

One of the most compelling methods to nurture student interest in STEM is to provide STEM experiences through extra-curricular activities. Research published by CBE-Life Sciences Education found that students who are exposed to extracurricular encounters are more inclined and interested in STEM [5]. Therefore, The Education Ministry is providing quality STEM experiences to students across the country in order to attract student interest in STEM. In addition, the ministry organised a STEM mentor-mentee programme in which teachers and students are partnered with STEM professionals and undergraduates to allow for a hands-on experience of the industry. The ministry has also invested in state and national-level STEM fairs where students collaborate and compete to apply their knowledge on STEM subjects and create innovations ("STEM literacy," 2018) This effort is expected to increase the number of students who will enrol in STEM subjects and courses.

Issues and Challenges

According to The World Economic Forum, an estimated 65% kids enrolling in primary education today will end up working in jobs that have not been created yet. In the era of



Industrial Revolution 4.0 (IR4.0), it is envisaged that the evolution of jobs continue significantly due to the way the industry works from conventional and manual approaches to automation and digitalisation approaches. Such transformation provides new jobs that require job seekers to have knowledge-based skills to stay relevant. At the same time, many current jobs that are featured are repetitive jobs, based on rules which involve well-defined physicality and are mostly likely going to shrink in number.

In order to sustain the demand on such jobs, it is important for the country to equip young generations with proper skill sets and strengthen STEM education. One of the efforts is to introduce programming language as the basic skill related to IR4.0 as early as possible to young Malaysians. The core technology of IR4.0 that includes cyber-physical systems, internet-of-things and cloud computing, is evidence that knowledge related to computing will take place as the central component of smart digital economy. Thus, programming language is without exception a basic skill that needs to be fostered among youth to make them stay relevant to the changes in the industry.

Learning programming is a medium for humans to communicate with machines via computer codes. More than that, programming can be used as a tool to improve youth logical thinking. While learning programming and understand computer codes can happen in a short time, building thinking skills requires a longer period. Earlier exposure will allow youth to master both programming and thinking skills well. They can apply these skills in various STEM fields as well as in language, economics and social sciences.

Therefore, the aim of this programme is to introduce and teach basic programming to primary school students using Scratch. The programme is expected to help students acquire Scratch programming knowledge via classroom training and problem-based programming group projects. A mentoring approach has been chosen for the knowledge transfer. The programme focuses on primary students of standard 5 to 6 (11 to 12 years old). As for the basic programming knowledge, Scratch 2.0 software is chosen. This software is an education and reference software developed by MIT. Scratch 2.0 uses a graphical programming block with interesting and colourful computer interface which can attract student attention. The aim of this study is to evaluate the effectiveness of the Scratch programming mentoring programme.

Computer Programming Education

Mentoring method is one of popular and effective forms of transferring knowledge between two parties, commonly from a person with the expertise, known as the mentor, to a person or group with least expertise (mentee) in the subject. The mentoring program usually involves guidance, support, advice and encouragement. Research shows that mentoring programs have improved academic performance (Zaniewski & Reinholz, 2016; Bunyamin & Finley, 2016).



Nonetheless, the design of the mentoring programs may be varied widely, and hence the effectiveness varies with different situations (Miller, Connolly & Maguire, 2011). Research that focusses on reading ability (Miller, Connolly & Maguire, 2011) showed that the most effective mentors are teachers and college students.

Mentoring program have also been adapted to promote and increase interest in STEM (Halim, Soh & Arsad, 2018), Zaniewski & Reinholz, 2016). In Zaniewski & Reinholz, (2016) each mentor is assigned to one mentee in a formal structured program. The assigned mentor and mentee are close in age, thus they are friendly to each other. However, the limitation of implementing this formal assignment method is lack of flexibility in choosing partners with mutual interest. This paper highlighted the perspective of a mentoring program established from mentor and mentee views. It was found that they have distinctive views on the program, where the mentors are more reflective on the mentor-mentee relationship, whilst the mentees viewed them as participants that need to fulfil the program requirements (Zaniewski & Reinholz, 2016). Although the mentees showed strong academic results, the exact impact of the mentoring program has been rarely measured.

The mentoring program not only has impact on the mentees. A study by (Nelson et al., 2017) investigated the impact of the mentoring program on the mentors. In this program, undergraduate and graduate students are paired and have been assigned as mentors to elementary and middle school students. The mentors provide after-school STEM activities by conducting hands-on activities. This program aimed to provide opportunity for the students to experience disciplinary topics and eventually promote their interest in studies and careers in the STEM field. The findings of this study showed that more than 90% of the mentors felt that the program is beneficial to them. It was also found that what they like most about the program is related to the youth (61.88%) and related to the lesson (37.62%) (Nelson et al., 2017).

Specifically in computer-programming education, mentoring programs have been found to be important in enhancing the beginner's interest as well as their skills in the subject. A study (D'Souza, 2008; Jayakumar,2016) highlighted the needs of a humanistic approach in order to improve the teaching and learning of the students in a programming subject. As quoted by the designer of the C++ programming language, Bjarne Stroustrup, (1991)" Design and programming are human activities; forget that and all is lost." It was found that, through a mentoring program, the human element was brought back into the teaching and learning processes, and hence improved the students' learning rate in the programming subject. It was also reported in the study that the conducted mentoring program has beneficial effects for both the mentors and the mentees.

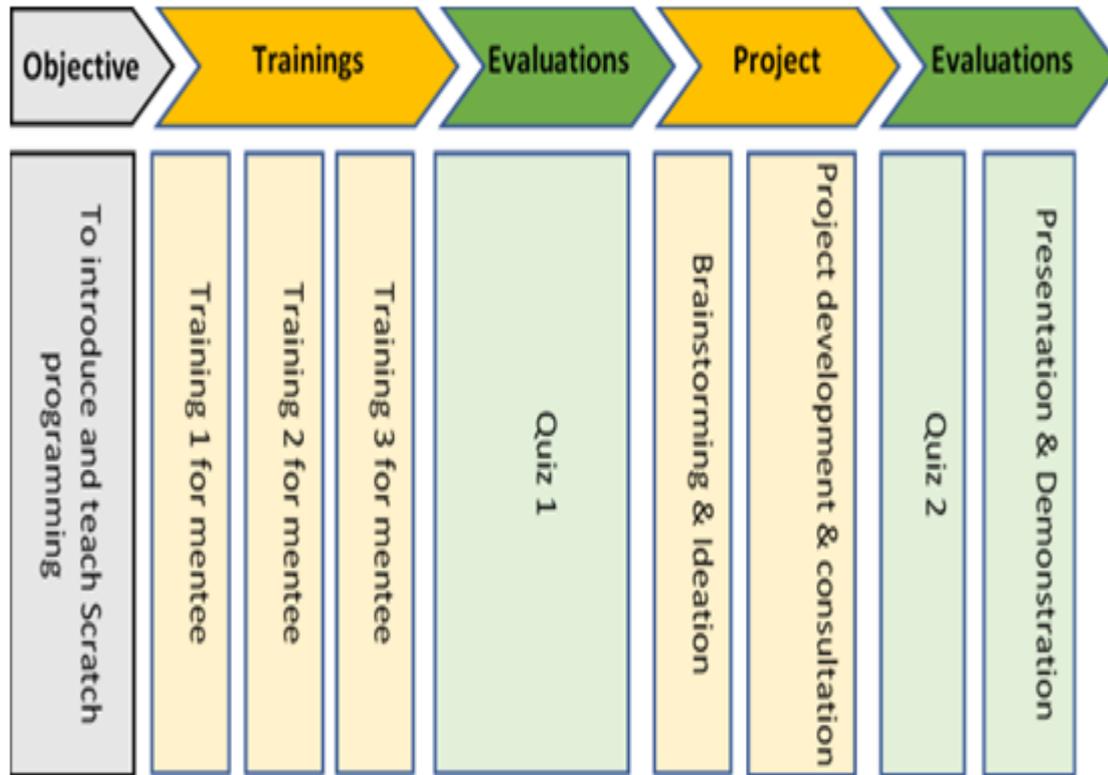


A mentoring program in order to help the beginners in programming was also conducted in Evey & Carbone, (2011). The program, which is known as Peer Assisted Study Scheme (PASS), is a face-to-face mentoring with selected excellent students from second and third years as the mentors and the first year students in the programming course as the mentees. The results showed that over 40% of students who participated in the program, achieved excellent grades in programming. It was found that poor attendance in this program contributed to the 29% of the failure rate in the programming course. Hence, it can be concluded that the face-to-face session or mentoring session has helped students to improve their skills in programming education.

Methodology

The Tyler Evaluation Model has been adopted in this study to develop and evaluate the Scratch Programming mentoring programme. Figure 1 below shows the structure of this programme. Firstly, the objective of the programme is determined. Then, the programme starts with Scratch programming training, followed by a quiz to evaluate student understanding. Next, a group project is assigned to the students. Finally, a second quiz and project presentation and demonstration were conducted for evaluation. In this study, a quantitative research approach is implemented. Statistical data are analysed from the designed instruments.

Figure 1. Overall structure of the research design



Programme activities

In this programme, two activities were implemented. The first type of activities are known as “trainings” activity. Participants of the program were being taught the fundamental knowledge of an interactive programming language called as “Scratch 2.0”. The training sessions were conducted by experienced university lecturers who teach and are involved in programming research. The training is designed such that lectures on the theoretical part are very minimal while most of the session time is spent on hands-on activities. During the hands-on activities, mentees were guided by mentors.

Three different sessions of the same modules were conducted with trained mentors who act as the facilitators during the training sessions. Training 1 and training 2 sessions took 2 hours to complete 4 basic modules. Meanwhile training 3 session was delivered in 4 hours for 2 advanced modules. The training modules used in this program is based on the book written by a former lecturer at Universiti Kebangsaan Malaysia as shown in Figure 2 below.

Figure 2. Reference book of training modules



Title: Seronoknya Belajar Scratch 2.0.
Author: Hafizah Husain.
Publishing date: 2017.
Publisher: Telaga Biru.
ISBN: 978-967-388-331-8

After completing the training sessions, type 2 activity called a “project” activity is performed. In the session, students are divided into groups. Each group is assigned along with a lecturer advisor, a teacher coordinator among two undergraduate student mentors.

Each group was assigned to conduct a problem-based project with the theme “game-based learning”. Students of each group were required to identify a problem related to their study in school. Mentors led the discussion, promoted elaboration of the problem and guided students to solve the problem by building a game-based program using programming skills they have learned. Here, the discussion was conducted in a session known as “brainstorming & ideation session”. At the end of the session, each group presented their idea and a suggested solution. Next, each group was given about 2 months to develop their solution. Students acted as the main developer of the solution while mentors were responsible for consulting their mentee in terms of any technical difficulty. The medium of communication between mentees and mentors during the development phase in via online communication i.e. Whatsapp group. In the final week of the development phase, a face-to-face session among mentees-mentors was conducted to finalise their complete solution i.e. working game-based program.

Participants

There are a total of 40 students involved in this program as mentees. The 40 students from standard 5 and 6 of various classes were selected by the teacher of Sekolah Kebangsaan Jalan 6, Bandar Baru Bangi. Those selected are the member of the school’s computer club. Demographic information about the selected students is presented in Table 1 below.

Table 1: Demographic information of the program mentees

	Gender		Standard	
	Male	Female	5	6
Number of students	23	17	18	22
Percentage	57.5%	42.5%	45.0%	55.0%

Besides students, the involvement of university lecturers as facilitators, school teachers as coordinators, university support staff as technical officers and undergraduate students as mentors also plays an important role in ensuring the project can be executed successfully. Table 2 below tabulates the number of participants in this program.

Table 2: Number of participants

Participants	Number of pax
Mentee (primary school's students)	40 pax
Mentor (undergraduate univ.'s students)	16 pax
Fasilitator (univ.'s lecturers)	8 pax
Coordinator (school's teachers)	4 pax
Support staff (university)	8 pax
Total	76 ax

Instruments

Two instruments are used to evaluate the achievement of participants. The first instrument is a set of quiz questions in the form of MCQ (multiple choice question) format. In this programme, two quizzes have been conducted. The first quiz was conducted after training was completed. Meanwhile, the second quiz was conducted after the project was completed. Quizzes were delivered via interactive online software called "Kahoot" and also in conventional paper-based quiz style. The questions are designed to test the ability of students to grasp the fundamental knowledge of topics covered in the study. The questions are divided into two categories:

- Deductive reasoning (5 questions)
- Inductive reasoning (5 questions)

Deductive reasoning questions assess the ability of students to apply theoretical knowledge into specific observation. This is accomplished through questions that require students to

translate a given problem into a programming code. On the other hand, inductive reasoning questions evaluate the ability of students to relate an observation into a specific theory. This is achieved through questions consisting an incomplete programming code for the student to debug and correct. Both deductive and inductive reasoning can be mapped into the logical thinking skill which is one of the main characteristics to become a good computer programmer.

The second instrument used in this study is the project's rubric. The rubric is prepared to assess the achievement of teams when completing their group project on game-based learning through presentation. There are 10 questions with 4 criteria for the rubric where the criteria are:

- Presentation delivery (3 questions)
- Design of solution (3 questions)
- Mastery of programming (3 questions)
- Teamwork (1 question) printing.

During the presentation session, 6 judges were appointed to assess each group performance. The judges were selected from 3 different backgrounds i.e. school teacher (3), lecturer (2) and technical officer (1). 8 groups of 5 members each were assessed.

Results and Discussion

This section is divided into 2 sub-sections to discuss the programming knowledge among primary school students through “training” and “project” activities of the program.

Scratch programming knowledge through training

In the final session of “training” activity, a quiz (Quiz 1) was conducted to assess the level of knowledge acquisition by students on the Scratch programming topics being teach. The results of students' answers are shown in Figure 3 below.

Figure 3. Quiz 1 results were categorised into 3 groups of Excellent, Good & Weak (n=30)

QUIZ 1 RESULTS CATEGORISED INTO 3 GROUPS

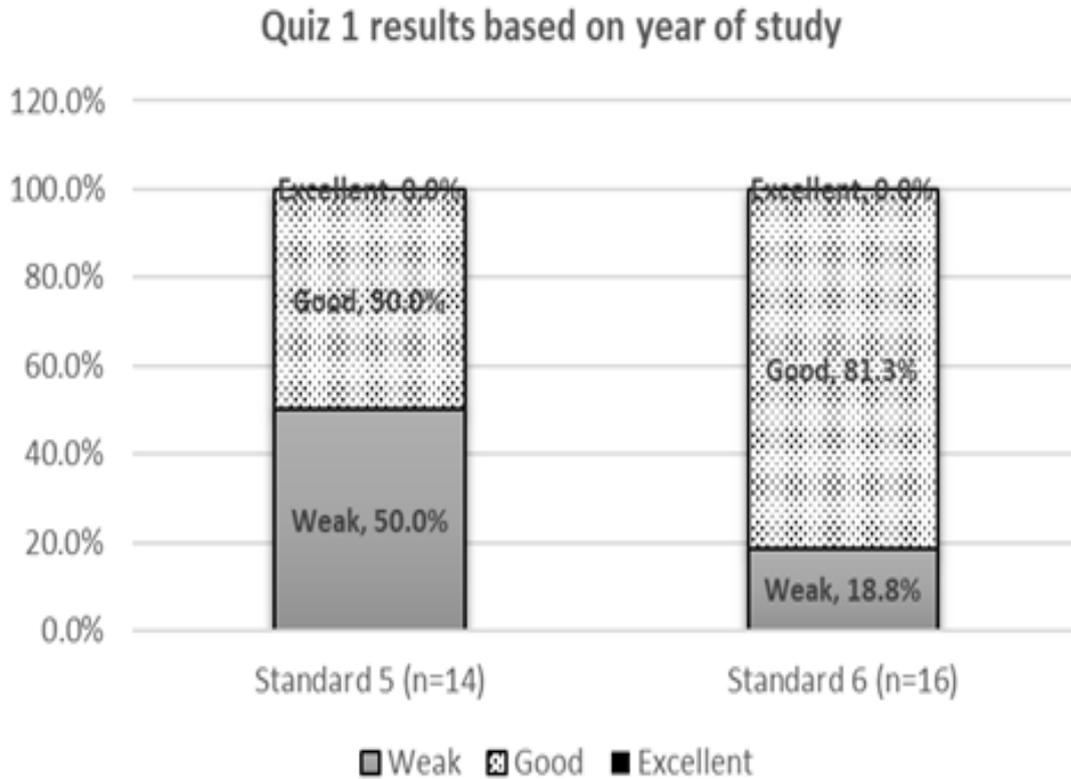


Mentees are categorised into 3 groups as follows based on their results:

- Weak – 0% to 39.9%
- Good – 40% to 69.9%
- Excellent – 70% to 100%

From the results of Quiz 1, it is revealed that no one has the mark above 70% or in the category of excellent. The distribution of marks reveals that 66.7% mentees are in “good” category while 33.3% mentees are in “weak category”. This study extends the analysis of the results based on students’ year of study as in Figure 4 below. It found that students in standard 5 with no prior knowledge on Scratch programming before joining the program are divided equally in “good” category and “weak” category. Meanwhile, for students in standard 6 with some prior knowledge on Scratch programming, they score better with 81.3% in “good” category while only 18.8% in “weak” category.

Figure 4. Quiz 1 results based on students' year of study, standard 5 (n=14) and standard 6 (n=16)



The third analysis on the results is based on answers on each question as in Figure 5. Note that the questions in the quiz have been arranged such that the first 5 questions relate to the deductive reasoning element and the last 5 questions are associated with the inductive reasoning element. From Table 3 below it can be seen that students are good at answering questions related to the inductive reasoning element with mean at 59.3%. On the other hand, questions relate to deductive reasoning element have a weaker score with mean at 20.7% only. Both reasoning elements can be related to the logical thinking ability of mentees.

Figure 5. Distribution of programming quiz 1 results by question number

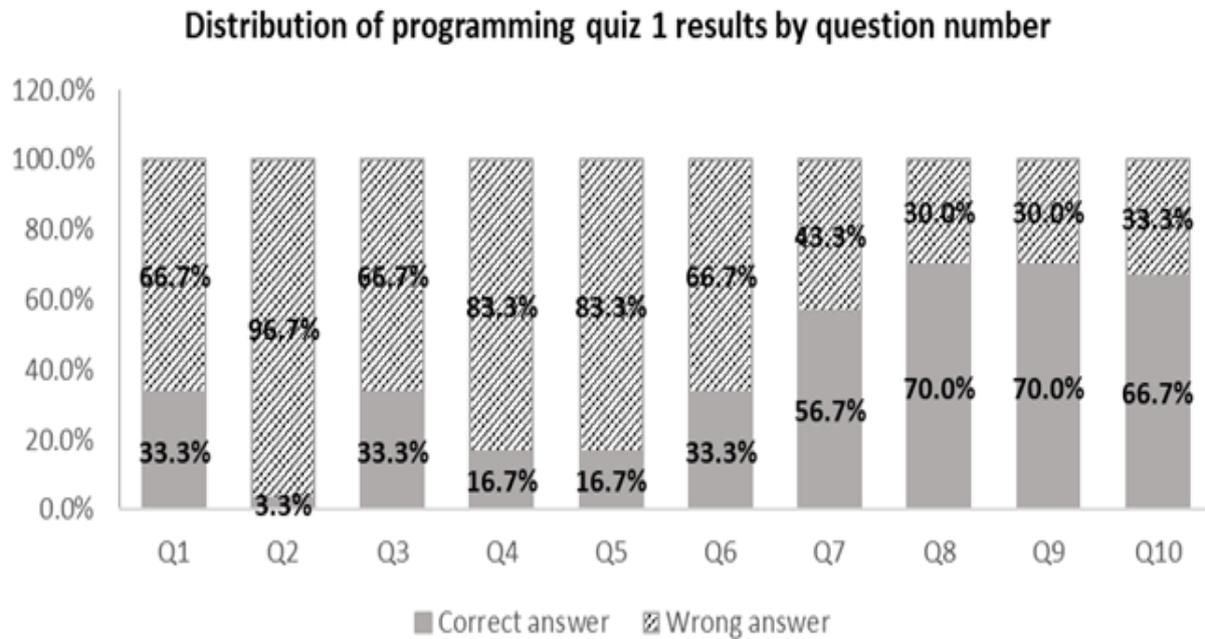


Table 3: Means of two type of questions correctly answered in quiz 1

Type of question	Mean
Deductive reasoning (Q1 – Q5)	20.7%
Inductive reasoning (Q6 – Q10)	59.3%

Scratch programming knowledge through project

“Project” activity is carried out after the “training” activities. Group project activity provides students with hands-on experience on using Scratch programming to solve real problems. At the end of this activity, another quiz is given to investigate if there is any gain in knowledge after performing the tasks of group project. Figure 6 below tabulates the results. It can be seen that the number of mentees in “excellent” category increases to 40.6%. The rest is divided into “good” category with 40.6% and “weak” category with 18.8%, respectively.

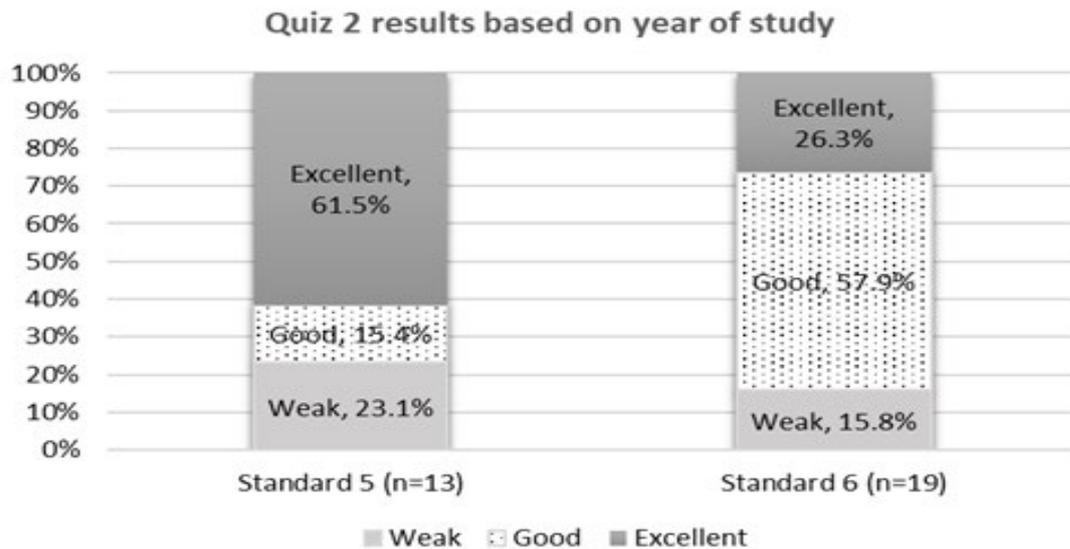
Figure 6. Quiz 2 results categorised into 3 groups of Excellent, Good & Weak (n=32)

QUIZ 2 RESULTS CATEGORISED INTO 3 GROUPS



Analysis based on student year of study found interesting results in that there are more standard 5 mentees in “excellent” category compared to standard 6 mentees. From Figure 7 below it is seen that there are 61.5% standard 5 students in this category, while only 26.3% standard 6 students are in the same category. For the “good” category, it is dominated by students from standard 6. There is also a remarkable improvement in the “weak” category where it tallies only 23.1% and 15.8% for standard 5 and standard 6 students, respectively.

Figure 7. Quiz 2 results based on mentee year of study, standard 5 (n=13) and standard 6 (n=19)



The final analysis was performed to observe the reasoning capability of mentees. Figure 8 below shows the distribution of answers based on question number. The first four questions relate to deductive learning and the last three questions to inductive learning. The calculation of mean on each reasoning types shows that the deductive reasoning of students improves from quiz 1 with mean at 52.3% while inductive reasoning slightly increases with mean at 61.5% as shown in Table 4 below.

Figure 8. Distribution of programming quiz 2 results by question number

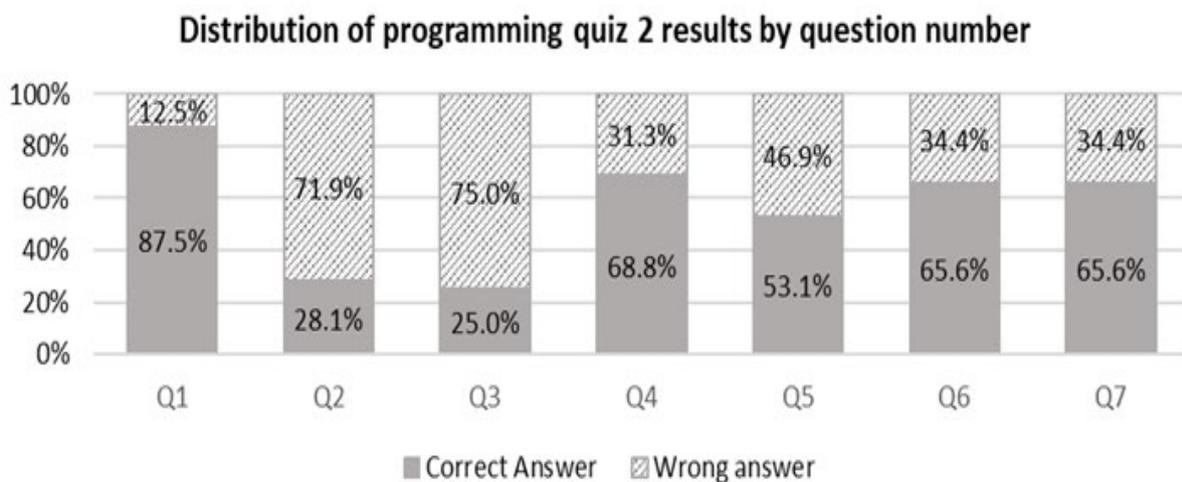


Table 4: Means of two type of questions correctly answered in quiz 2

Type of question	Mean
Deductive reasoning (Q1 – Q4)	52.3%
Inductive reasoning (Q5 – Q7)	61.5%

With training activities, this study found that students with basic background of programming i.e. standard 6 students dominate the percentage of “good” and above for programming knowledge. Meanwhile, standard 5 students with less or no prior knowledge of programming, score less. However, after the project activity, this study reveals that the ability of standard 5 students is at par with standard 6 students. Even better, the number of students in the “excellent” category of knowledge acquisition level is dominated by standard 5 students. This statement can be cross-validated with the fact that all project groups are able to achieve a game-based learning program proposing solutions for various subjects.

In terms of reasoning skill, this study found that initially students are lacking in deductive reasoning capability. However, after finishing the programme, their deductive reasoning is on par with inductive reasoning capability. This may be contributed to by the activities in project mode where they need to use their programming knowledge in order to translate their problem in learning a topic of a subject into a game-based learning program.

Observation of Teachers and Lecturers on Mentees

In this study, teachers and lecturers are able to evaluate the performance of students during the presentation of a project outcome at the end of the project activity. A project rubric was prepared for teachers and lecturers to evaluate the achievement of each project group. The rubric assesses the overall achievement of students in conducting, presenting and demonstrating their project outcome. 3 teachers, 2 lecturers and 1 assistant engineer were appointed as judges to evaluate group achievement. There are 10 questions categorised into 4 criteria i.e. presentation delivery, conduct of project, mastery of Scratch and teamwork, assessed by the judges. However only questions on mastery of Scratch (labeled as C1 – C3) are the focus of this study. The rubric scales are from 0 to 5, where 0 represent none, 1 – very weak, 2 – weak, 3 – moderate, 4 – good and 5- excellent. Table 5 shows mean and standard deviation of average score of all groups on each question from category mastery of Scratch. As shown in Table 5 below, mean for all three items are above moderate.

Table 5: Mean and standard deviation of average score of all groups on each question of project rubrics

Question ID	Question	Mean	Std. Dev.
C1	Basic skills of Scratch programming	3.854	0.653
C2	Usage of complex block: variables, questionnaires, broadcasting, etc.	3.500	0.577
C3	Shows interest in Scratch	3.771	0.485

Based on the results of this study, the Scratch programming mentoring programme manage to help primary students from Sekolah Kebangsaan Jalan Enam to learn and increase their Scratch programming knowledge.

Conclusion

This study aims to evaluate the Scratch programming mentoring programme for primary school students. The programme intended to strengthen student skill in basic computer programming which becomes an important tool for IR4.0 jobs. The mentoring program was conducted with two major types of activities. The first type of activity is classroom training. The training is designed such that lectures on the theoretical part are very minimal while most of the session time are spent in hands-on activities. The second type of activity is project-based learning. Students were divided into groups where each group is assigned the development of an interactive game-based learning tool by using programming. The results and statistics show that the combination of training and project-based activity improved student programming and reasoning skill and components of logical thinking capability.

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