Effects and challenges in teaching robotics for elementary students

دراسة الآثار و التحديات في تدريس علم الروبوتات لطلاب المرحلة الابتدائية

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Abstract

Developing the curriculum to support the students' abilities and talents especially in the field of problem-solving and critical thinking is one of the most important objectives that the UAE seeks to achieve. The purpose of this study is to explore the effect of teaching robotics for elementary students to understand the basic concepts of programming. In addition, the study aimed to investigate the challenges of teaching robotics for elementary students as well as the effect of educational robotics on students' problem-solving and critical thinking skills. The applied programming language is based on programming blocks, and the target group of students is fourth grade students in one American Curriculum School. The number of participants students was 115 students, and he data of this study were gathered through conducting observations, questionnaire, and multiple programming assessments. The process of teaching robotics and programming for the students continued for 11 weeks. After that, the students were asked to solve different programming assessments. The programming assessments conducted three times during robotics course to show the progress of the students' programming skills. The assessments were applied to evaluate the impact of depending on teaching robotics as main way to teach programming. The results of study showed that using educational robotics is an effective tool that increase the students' engagement and interest levels in the classes and to develop the students' problem-solving and critical thinking skills. Additionally, the results indicated that using programming blocks to teach programming helps the students to understand the majority of many programming concepts, but at the same time some concepts were difficult for the students to understand and apply.

الخلاصة

تسعى دولة الإمارات العربية المتحدة إلى تطوير المناهج التعليمة لدعم قدرات الطلاب و مواهبهم، و خاصة في مجالات حل المشكلات، التفكير النقدي، و المهارات التقنية. يهدف هذا البحث إلى استكشاف التحديات التي تواجه المعلمين في تدريس البرمجة، بالإضافة إلى دراسة الآثار المترتبة على تدريس الروبوتات لطلاب الابتدائي و ذلك في مجال نطوير مهارات الطلاب و فهم مبادئ و أساسيات البرمجة. استخدمت سلاسل البرمجة في برمجة الروبوتات، كما اعتمدت كوسيلة أساسية لشرح مبادئ و أساسيات البرمجة. أجريت هذه الدراسة على طلاب الصف الرابع الابتدائي في إحدى المدارس الخاصة التي تعتمد المنهاج الأمريكي، و قد بلغ عدد الطلاب المشاركين 115 طالباً. تم جمع بيانات هذا البحث عن طريق استبيان يشمل أسئلة متعددة حول منهاج الروبوتات، إجراء عدة اختبارات في البرمجة، و تسجيل الملاحظات على أداء الطلاب خلال حصص و اختبارات الروبوتات. استغرقت مدة البحث إحدى عشر أسبوعاً تشمل الحصص الدراسية و الاختبارات، و قد تم إجراء ثلاث اختبارات بهدف دراسة مدى تطور مهارات الطلاب في البرمجة. أشارت نتائج البحث إلى أن الروبوتات تعتبر وسيلة فعالة في زيادة اندماج و استمتاع الطلاب خلال الحصص الدراسية، و تطوير مهاراتهم في حل المشكلات و التفكير النقدي. و أشارت نتائج البحث أيضاً إلى أن استخدام سلاسل البرمجة يساعد الطلاب في استيعاب معظم مفاهيم البرمجة، و لكن في بعض الأحيان توجد مفاهيم يصعب على الطلاب فهمها و تطبيقها.

Dedication

This dissertation is dedicated to my family and friends for their endless support. A special grateful feeling for my Mom who was my source of inspiration, who gave me strength when I thought of giving up, and who was continually providing me with her moral, spiritual, and emotional support to complete my Master's degree. Thank you for your prayers and patience throughout this journey.

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Chapter One: Introduction:

Educational robotics has emerged and applied as a main and valuable tool in programming curriculum in many schools. Robotics and programming developed critical thinking, problem solving, and collaborative skills, which are important to acquire for the next generation students. (Afari and Khine, 2017)

Robotics provides an attractive learning environment which increases the students' desire to learn and the students' confidence to ask and find answers to solve real-life problems. Robotics education provides the opportunity for the students to build and program different types of robots in accordance of learning standards of STEM (Science, Technology, Engineering, and Math) subjects. (Afari and Khine, 2017) Some studies reported that teaching robotics and programming for students increases the students' personal and social skills including creative thinking, decision making, communication, and team working skills. (Afari and Khine, 2017)

In addition, educational robotics motivates the students especially who acquire gifts and talents to learn the needed skills and knowledge to achieve their goals to complete the projects of their interests. (Afari and Khine, 2017)

Elementary students always require modifications in the taught curriculum and the applied teaching methods to understand the taught concepts in their curriculum. They need challenging tasks and questions to increase their critical thinking and problem-solving skills. Moreover, educational challenges support and enhance the innovation and creativity levels of the students.

UAE aims to be one of the most innovative nations in the world in seven main sectors. Two of these sectors are education and technology. (Arabian Gazette, 2019) UAE followed different strategies to achieve this goal. One of these strategies is supporting and motivating students by providing them with developed curriculum and educational tools, conducting competitions, and providing them with valuable rewards. The educational authority in Abu Dhabi, Abu Dhabi Educational Council (ADEC), promoted the use of robotics in schools as an educational tool. ADEC aims to increase the students' engagement level in education through creative activities that require STEM related knowledge. (Afari and Khine, 2017)

1.1. Research objectives

The aim of this study is to measure and evaluate the effect of teaching robotics and programming for elementary students as a main tool to understand the basic programming concept, and to increase the students' critical thinking and problem-solving skills. In addition, the study aims to find out the challenges in teaching programming for elementary students.

The study was applied in one Private American Curriculum School in UAE which adopts teaching programming for different grades levels. According to the school's ICT (Information Communication Technology) curriculum, teachers start teaching programming with grade four students, then they continue teaching programming for grades 5, 6, 8, 9, 10, and 12 students. During these teaching levels, the teachers cover different programming concepts and use various programming tools and languages.

The sample of the conducted study includes 115 students in grade four, and they were taught programming and robotics for two months and three weeks, and the teacher assessed their understanding levels by applying multiple assessment tools. During this process, the students were observed, and different notes were written about their engagement and achievement levels. After that, they were asked to solve different programming questions and fill a questionnaire. In addition, during the evaluation process, the students were observed, guided, and their answers were checked. The teacher provided the students with different challenging questions in the learning and evaluating processes.

1.2 Research questions

The study aims to answer the following questions:

I. How does engagement in the robotics activity influence the students' interest and self-efficacy during robotics classes?

II. What are the challenges in teaching robotics and programming for elementary students?

III. How does teaching robotics affect the students’ problem solving and critical thinking skills?

IV. Is teaching robotics a useful tool to teach programming for elementary students?

Chapter Two: Literature Review

This section provides a review of previous related work and explores their implementations in the field of teaching programming for students as a part of ICT curriculum. This section discusses multiple areas in this field to get deeper knowledge into teaching robotics and programming in schools.

2.1 The effect of computer programming:

The educational standards aim to develop the skills of the next generation students in line with the future's requirements and challenges. Many studies conducted to measure the effect teaching robotics and programming to develop the students' problem-solving and critical thinking skills. This section discusses six studies that investigate and explore the effects and challenges of teaching programming by using different programming languages and tools. It also compares the implementations of the discussed studies with the proposed study of teaching robotics and programming for elementary students.

(Afari and Khine, 2017) study aimed to explore the used of educational robotics in schools, and it could be integrated into the curriculum. In addition, it suggested some strategies to be conducted to increase the students' interest in STEM (Science, Technology, Engineering, and Math) related subjects. It also provided some recommendations to enhance the learning activities in the classrooms. The author used Lego Mindstorms Kit and its' programming tool to teach programming to the students in a way that enhance their skills. This is because Lego Mindstorms Kit gives the students the opportunity to build, plan, and program different types of robots which have the ability to perform different tasks. (Afari and Khine, 2017)

The educator played an important role in (Afari and Khine, 2017) study because he did not transfer the information directly to the students. Instead of this, he facilitated the learning process and led the students in their group work, which affected the students' abilities to think critically and solve different types of problems. Educational robotics provides a learning environment to the students in which they can interact and work with real-life problems. (Afari and Khine, 2017)

The methodology of (Afari and Khine, 2017) study based on the way of teaching robotics. Robotics lessons have two main roles, the educator's and the students' roles. The educator should offer different opportunities to the students to explore new information and concepts, and he should provide the students with appropriate tools to increase the students' engagement during robotics classes.

The students were divided into groups, and they should explore, plan, and build different robots that can solve problems which people may face in real-life. In addition, students should share the obtained results with their friends. (Afari and Khine, 2017)

(Afari and Khine, 2017) study concluded that teaching robotics has a great effect in enhancing the students' critical thinking and problem-solving skills, and it enables the students to participate in competitions which increased the students' self-confidence and innovation.

The aim of (Afari and Khine, 2017) study and the followed way in teaching robotics are the same with the proposed study. The differences between them are the target group of students and the conducted methodology. The proposed study targeted only elementary students, while (Afari and Khine, 2017) study all elementary and secondary students.

The proposed study conducted multiple research instruments to collect the data, which were observations, different programming assessments, and questionnaire to evaluate the students' performance and their engagement level during robotics classes.

The methodology in (Afari and Khine, 2017) study depended on the educator's and the learners' roles in teaching robotics to measure the effect of robotics in enhancing the skills of the students. In contrast, the proposed study conducted a qualitative methodology to investigate the effect and challenges of teaching robotics for elementary students.

The second issue of programming courses is that most students start studying programming at universities which makes it very hard for them to understand the programming concepts.

The second study was (Mihci and Ozdener Donmez, 2017) study that aimed to investigate the short and the long-terms effects of teaching programming by using GUI-oriented visual blocks-based programming language (BBL) as a second-tier tool. This programming tool visualizes the programming concepts in blocks that have different colours and images that describe the programming concepts. Teaching programming is one of the big challenges that faces teachers and students and affects the students' performance in universities. Many researches stated that many students dropped out their programming courses or even changed their Bachelor major that includes IT programming courses. This happened due to the difficulty of programming courses. The results of these studies prompted the researchers to find a solution that helps the students in studying and understanding programming concepts. One of these solutions is teaching programming for the students before joining the universities. This solution will enable the students to accommodate and understand the programming courses in the universities. (Mihci and Ozdener Donmez, 2017)

The idea of using programming blocks is to facilitate studying and understanding the programming courses for the students. (Mihci and Ozdener Donmez, 2017)

The effects of the conducted methodology in (Mihci and Ozdener Donmez, 2017) study were measured based on the students' academic success in programming and on the professional opinions and preferences in the programming education's context.

(Mihci and Ozdener Donmez, 2017) study conducted the research by dividing the candidate teachers into two groups. The first group was the teachers who were taught programming using text-based language (TBL) as a first-tier tool. During this phase, the researchers formulated two hypotheses.

Firstly, the academic success of the teachers who were taught programming with text-based language will be less than the group who were taught programming with blocks-based programming language. (Mihci and Ozdener Donmez, 2017)

Secondly, the use of (BBL) instead of (TBL) will have a great influence to be either experienced or novice on the students who are joining the universities. (Mihci and Ozdener Donmez, 2017)

The second group included two types of teachers; some of them were taught programming by using both (BBL) and (TBL), while the others were taught programming by using only (TBL). The second group was conducted to collect teachers' opinions and preferences on teaching programming as a main education subject in schools. The researcher also formulated two hypotheses about the teachers' opinions. (Mihci and Ozdener Donmez, 2017)

Firstly, the teachers will specify the starting age of teaching programming. Secondly, the researchers will collect the teachers' opinions in both groups about their preferred programming language for teaching programming. (Mihci and Ozdener Donmez, 2017)

The methodology of (Mihci and Ozdener Donmez, 2017) study included two phases. The first phase was following quasi-experimental pattern and analyzing quantitative data statistically.

In the second phase, the researchers conducted a case study, and they gathered qualitative data from the groups and analyzed the data by coding text content.

The results of (Mihci and Ozdener Donmez, 2017) study stated that the students who used (BBL) achieved higher academic success in comparing with the students who used (TBL). On the other hand, the students who were familiar with text-based programming had shown failure in adapting (BBL).

At the end, the researchers found that (BBL) had not been entirely an effective and suitable tool to teach programming for younger students.

The objectives of (Mihci and Ozdener Donmez, 2017) study was similar to the objectives of the proposed study. Bothe studies aimed to measure the effect of depending on programming blocks to teach programming concepts for young students. The differences between both studies were in the conducted methodologies. (Mihci and Ozdener Donmez, 2017) study collected and analyzed quantitative and qualitative data, while the proposed study collected only qualitative data.

(Korkmaz, 2016) and (Ortz, 2015) studies have the same objectives as the conducted study in this paper as well as the discussed studies in this section. Computational and critical thinking as well as problem-solving skills have been increasingly required for acquiring and implementing programming skills. (Korkmaz, 2016) study aimed to investigate the effects of Lego Mindstorms EV3 programming activities and Scratch on academic achievements and acquiring critical thinking and problem-solving skills by the students.

The dataset of (Korkmaz, 2016) study was 75 university students who were divided into three groups, two experimental groups and one control group. Group 1 used Scratch-based activities, group 2 used Lego Mindstorms EV3 based activities, whereas the control group used C++ editor-based activities.

The methodology of (Korkmaz, 2016) study included pre-test, experimental manipulation, and post-test phases. Multiple academic, logical-mathematical, problem-solving tests were conducted in the pre-test and post-test phases. During the experimental manipulation phase, the three programming tools were used, each tool for a specific group. The performed tests during the post-test phase were conducted to measure and investigate the effects of teaching programming on the students' skills and academic levels. The results of (Korkmaz, 2016) study were analysed and evaluated by using athematic mean, standard deviation, percentage, frequency, and ANOVA analyses. The results stated that Scratch-related game activities made positive effects on students' logical-mathematical thinking skills compared with the effect of Lego-Mindstorms EV3.

(Ortz, 2015) study had two goals behind using Lego robotics materials as a learning tool. Firstly, the study aimed to determine if the intensive extracurricular activities would lead the students to deeply understand the concepts in their curriculum. Secondly, it aimed to explore if the mathematical problem-solving skills of the students will be developed after participating in robotics activities. The dataset of the study was 30 students who were divided into two groups, 15 students in each group. At the beginning, the participants students applied for one-week mathematics program. After the program, the students were assigned either to the intervention group, or to the comparison group. The study included two conditions, learning of ratios and proportions in a non-engineering textbook-based mathematics intervention program and learning of ratio and proportion in an integrated engineering and mathematics intervention program. The idea of dividing the students into two groups, was comparing the students' understanding of the mathematical concepts between the intervention and the comparison groups. The students' results were collected and analysed at the beginning and at the end of the mathematical intervention program. Additionally, the results were collected and analysed after weeks of the intervention program.

The results of the study indicated that designing Lego robotics engineering and programming in an integrated context helps the students in understanding new concepts of ratio and proportion. In addition, it stated that short and intensive learning courses showed a significant change in the students' understanding of ratio and proportion regardless to the type of the intervention program they had been assigned. The students' performance in the experimental group was higher that the students' performance in the control group. Finally, the results stated that engineering related context helps the students in understanding and remembering the mathematical concepts for a long time.

The methodology of (Korkmaz, 2016) and (Ortz, 2015) studies differ from the methodology of the proposed study in measuring the effects of teaching programming by including control group. (Korkmaz, 2016) and (Ortz, 2015) studies conducted a quantitative study, while the proposed study conducted a qualitative study.

(Wang, Huang and Hwang, 2015) study indicated that the major methods of teaching programming are based on programming language syntax and the programming skills, while problem-solving concepts are ignored. The aim of the study is proposing an integrated Scratch and project-based learning approach to support students' problem-solving strategies. (Wang, Huang and Hwang, 2015) study evaluated the effect of the conducted approach by asking a group of talented students to solve different programming questions by using scratch software and apply project-based learning activities. The data sample of (Wang, Huang and

Hwang, 2015) study was 91 students, including 43 normal students and 48 mathematics-gifted students.

At the beginning, the students were asked to browse the internet and search for information about viruses, and then developed a script for their team project. After that, the students needed to organize the important characters and objects by using software for image processing, and then use Scratch programming tool to produce the project. The researchers conducted prior knowledge assessment to evaluate the students' starting abilities, learning motivation, and attitudes. (Wang, Huang and Hwang, 2015)

The students' learning procedure consisted of four learning phases. The first learning phase included identifying the project goal and the problem-solving strategies to achieve the identified objective. The project's goal and the proposed strategies will be explained via scripts and flowchart. In the second phase, the students were asked to develop the scripts and the flowcharts based on the provided materials from the teacher and the acquired information from the internet. (Wang, Huang and Hwang, 2015)

The third phase was introduction to programming concepts and programming tools in Scratch. In the last phase, the students were asked to develop digital story by using Scratch software. At the end, the students' learning outcomes were evaluated by conducting post tests and questionnaires to measure the learning attitude, motivation, and technology acceptance of the students. (Wang, Huang and Hwang, 2015)

(Wang, Huang and Hwang, 2015) study's results indicated that project-based learning approach increased the students' learning engagement, and helped them to be initiative to explore, create, and construct new knowledge.

In addition, the results showed that gifted students can use Scratch programming tool to develop their critical thinking and problem-solving skills. (Wang, Huang and Hwang, 2015)

(Wang, Huang and Hwang, 2015) and the proposed studies have the same objectives, and both followed qualitative methodology to find out the effect of teaching robotics on students' problem-solving skills and their learning engagement during robotics classes. The difference between them is that (Wang, Huang and Hwang, 2015) study included analyzing the results of gifted students, while the proposed study targeted all fourth-grade students.

(Kandlhofer and Steinbauer, 2016) study was an empirical study that investigate the effects of using robotics on the technical and social skills, as well as the science related attitude and interests of students. The study took 8 months in different schools in Sweden and Austria. The study followed quasi-experimental two-group design conducted two assessments tools, pre- and post-tests. In addition, the researchers a survey as an additional assessment tool. The results were analyzed and organized into multiple categories: Math and Science investigation, teamwork and social skills, as well as the technical skills. Correlation analysis stated that applying robotics as an educational tool has positive effects in developing and enhancing all the targeted skills in the study. (Kandlhofer and Steinbauer, 2016)

2.2 Robotics education for secondary students:

The constructivist educational methods are highly required to create an attractive and very useful learning environment. (Tocháček, Lapeš and Fuglík, 2016) This section discusses five studies that were conducted in secondary schools and were interested on this topic.

(Tocháček, Lapeš and Fuglík, 2016) study aimed to identify the aspects and the results of using educational robotics in educating at secondary schools, especially in the field of developing the technological knowledge and programming skills for secondary schools' students. The idea of (Tocháček, Lapeš and Fuglík, 2016) study is providing a constructive learning environment for students, will transfer the students from the stage of receiving knowledge to the stage of producing knowledge. The students will be able to create new knowledge because the educator will focus on increasing the students' innovation and developing their critical thinking and problem-solving skills.

(Tocháček, Lapeš and Fuglík, 2016) study followed three phases in its methodology. In the first phase, the researchers prepared the curriculum of the educational robotics course and created an extensive database of the electronic materials.

In the second phase, groups of secondary schools' students, educators, and trainee teachers attended the educational robotics course. The (Tocháček, Lapeš and Fuglík, 2016) research's participants were 11 educators, 19 trainee teachers, and 79 secondary students enrolled for the course. They attended six educational sessions, each session lasted for five hours. The first two sessions were theoretical sessions, while the last four sessions were practical sessions. In the last practical session, the students were asked to build and program their own robots.

During this phase, the researchers followed qualitative research methods to collect the required information. They conducted interviews with the participants, and recorded observations about the participants' engagement and performance during the robotics classes. At the end of the second phase, the researchers evaluated and analysed all the collected information. In the last phase, the researchers used the analysed information to prepare complete electronic course manuals and developed the needed educational materials to be used in the future educational robotics courses. (Tocháček, Lapeš and Fuglík, 2016)

The researchers in (Tocháček, Lapeš and Fuglík, 2016) study noticed an unusual excitement over the courses, and the participants were able to create their own robots based on the acquired knowledge during the courses. The participants achieved 58% of high-quality projects, and they were presented in timely manner. In addition, 29% of the conducted projects were standard quality, and the remaining 13% of the projects were of poorer quality, but at least they met the requirements. The results verified the educational robotics is a powerful pedagogical methodological tool to develop the technological knowledge and programming skills of secondary schools' students, and it leads to increase the quality of educational process at all.

(Ospennikova, Ershov and Iljin, 2015) study is the second study which aimed to investigate the use of robotics in secondary schools' classes in Russia as a tool for teaching programming, Math, Science, and Physics. The study was conducted on 186 school students from grade 7 to grade 9. The researchers worked systematically with the students, and they covered three training technology's fields. The training fields were robots as a study object, robots as a teaching tool, and robots as a tool of developing and enhancing students' skills.

The researchers in (Ospennikova, Ershov and Iljin, 2015) study conducted a qualitative study to find out the students' accommodation, acceptance, and performance in the three training fields. The results of the study stated many positive effects on using robots as an educational tool.

Firstly, robotics classes enhanced the students' abilities in acquiring new knowledge, skills, and mastering the universal academic actions. This is due to the cognitive thinking processes during the robotics classes. Secondly, the researchers found that the students' understanding of Science and Physics concepts became better, and students acquired knowledge's classification and generalization skills. Finally, the researchers found that robotics classes developed the required students' skills in cognitive processes; such as: perception, presentation, imagination, thinking, memory, speech, and innovation. (Ospennikova, Ershov and Iljin, 2015)

(Atmatzidou and Demetriadis, 2016) study also targeted the secondary students to investigate the use of educational robotics as a tool to develop the students' computational thinking skills. The number of students who participated in the study was 164 students, and they were divided into two groups, Junior high: 89; High vocational: 75. The students' ages were 15 and 18 years old. The study employed a suitable critical thinking model to operate and explore the development of the students' critical thinking skills based on their ages and gender. The researchers conducted multiple educational robotics learning activities for 11 weeks, each lasted for 2 hours per week. During the methodology phase, the researchers conducted interviews and questionnaires to find out the students' opinions about the training activities, and they recorded their observations about the students' performance and engagement levels during robotics sessions. The critical thinking skills of the students were evaluated at different phases during the training sessions by applying written and oral assessment tools.

The results of (Atmatzidou and Demetriadis, 2016) study stated that critical thinking skills need a lot of time to be developed, and the assessment's modality has a great effect on the students' performance. In addition, they found that girls in many cases need more time than boys to reach the same skill level. At the end of the educational training sessions, all boys' and girls' students reached the same level in critical thinking skills development.

All the discussed studies in this section followed the same methodologies and used the same research instruments to investigate the effect of educational robotics in developing the students' critical thinking and problem-solving skills. The methodologies and the results of the discussed studies are similar to the proposed study, while the participants of the proposed study were only elementary students.

(Sasithorn Chookaew, 2018) study was conducted in Thailand to set the foundations of the teaching plans that target the secondary school's students. The methodology of the study based on conducting a workshop about STEM learning that used robotics as an educational tool. The purpose of using robotics is to develop the students' innovation and computational thinking skills. Robotics also provide the students with a challenging learning missions that enhances the students' performance in STEM subjects. The workshop included 8 sessions, and it lasted for three days. The participants in the study were 60 male students from one public high school in Thailand.

The methodology instruments in the study were the students' scores during the workshop, semi-structured interviews with the students, and a questionnaire. The interviews were conducted to evaluate the students' critical thinking, problem-solving, and computational thinking skills. The aim of the questionnaire was assessing the students' engagement level during the workshop. The researcher divided the students into two groups based on their scores in the workshop. The students who got high scores in the workshop, they provided the educator with creative solutions to solve the problems. In contrast, the students who got low scores, they provided logical solutions to solve the problems. The solutions were lack of creative ideas. In general, the results showed that robotics is a useful tool to develop the students' skills. (Sasithorn Chookaew, 2018)

(Sasithorn Chookaew, 2018) study has the same objectives and followed the same methodology of the proposed study. The differences between them is targeted students, and duration of teaching robotics. Teaching robotics in the proposed study was part of the students' curriculum, while teaching robotics in (Sasithorn Chookaew, 2018) study was course for only three days.

(Ouahbi et al., 2015) study evaluated the use of Scratch in motivating the students toward learning. Many studies documented that there are many difficulties faced by the students in understanding the programming concepts. (Ouahbi et al., 2015) study suggested the use of games to increase the students' motivation and develop their knowledge in an effective way. The participants in the study were 69 high schools' science major students, who were divided into three groups. The first group used Scratch tool to create simple games, while the second and third groups used Pascal programming language.

At the beginning and end of the study, the students filled two surveys. The purpose of the surveys was identifying the students' programming level, gaming habits, motivation and interests for continue studying programming in the future. The surveys' results showed that 65% of the students who used Scratch in their learning, preferred to complete their studies in programming, while only 10.3% of the students who used Pascal showed their interest in programming. The analysis of the survey showed that Scratch is an effective programming tool that motivates the students in studying programming. (Ouahbi et al., 2015)

2.3 Robotics education for elementary students:

This section presents five studies that discuss the use of educational robotics to enhance different skills for elementary students.

(Casler-Failing, 2018) study described the use of Lego robotics to develop the narrative writing skills among 5^{th} grade students. The study relied on conducting courses over four weeks, one session per week. During the courses, the students learned how to build and program robots, assign a mission, write and present a proposal to complete the identified mission, and connected what they have learned with their personal experiences. The starting activity was presenting the students' knowledge about the second World War and Hiroshima.

After studying the basics of building and programming robots, the educator presented a scenario about the effects of bomb drop in Hiroshima. After that, the students were asked to work in pairs and took the role of engineers to create a proposal. The proposal should include information about the problem and some suggested solutions to solve it. When the students completed their proposals, they presented them in front of their friends, and they asked for approval from their educator. After accepting the proposals, the students started building and programming their robots according to their proposed solutions. Programming the robots required applying of mathematical skills to measure the distances, which is part of the robotics course.

The students were also asked to write their reflections which were an indication about the students' understanding, and it was an additional writing activity. The last activity in the course was a narrative writing to connect the event of Hiroshima with the students' personal experience about Hurricane Irma. In the first and second sessions, the students asked a lot of questions about writing the proposal, their writing poorly answered the questions posed, and many writing samples included incomplete sentence structure. By the third session, writing process was easier for the students because the students were engaged during robotics classes, and they had many ideas about the problem. Therefore, the students were able to write and present their reflections. (Casler-Failing, 2018)

In the last session, all the students wrote the required narrative easily although they were not excited about the writing aspect. Some students asked for more papers to complete their writing. All the writing documents by the students showed their progress in writing skills. The idea of the study is that conducting activities that enable the students represent the ideas in models, provide the students with many ideas and opinions. As a result, the students can write and express their opinions easily. In addition, the results showed that robotics is an effective tool that provides an exciting learning environment, and it help the students to model any required ideas which will develop and enhance the students' writing skills. (Casler-Failing, 2018)

(Toh, 2016) study was a systematic review that synthesized the findings of research studies over ten years, and it investigated the influences of robotics on young students and education. The study examined four major factors: the types of the conducted studies, the effects of robots on the children's behaviours and developments, the opinions of the stakeholders on educational robotics, and finally the children's feedbacks and reactions on robotics. The review showed and discussed the conducted approaches by the researchers which included non-experimental and quasi-experimental methods. The paper also presented the influence of robotics on children, grouped into four main categories: conceptual, cognitive, social, and language.

The study reviewed 27 out of 369 articles based on multiple criteria. The results of some papers indicated that robotics developed the students' academic skills in understanding the concepts of Math, Science, and Engineering, and it improved the students' scores. In addition, the results of the studies stated that the interaction during robotics allows the students to increase their engagement level and express their opinions which developed the students' language skills. (Toh, 2016)

The discussed studies in this section targeted the same age group of students and they followed the same conducted methods in the proposed study, while the difference between them in the objectives behind using educational robotics.

(Charoula Angeli, 2016) and (Budiyanto, 2018) studies reviewed the impact of applying computational thinking on education.

(Charoula Angeli, 2016) study discussed the idea of adding computer science subject to K-6 curriculum. The study addressed two challenges according to this issue. The first challenge was the design of computer science curriculum which should focused on real-life problems. Secondly, the knowledge that the teachers should acquire to teach computational thinking curriculum.

The idea of the study is that technology plays an important role in our daily-life, and people should acquire a lot of knowledge and skills to deal with it. The most and the most important step is that starting teaching computer science in schools, and it is important to start with lower grades to make it easy for the students to understand and apply the computational thinking concepts. (Charoula Angeli, 2016)

The study described the framework of computational thinking that should be followed in K-6 curriculum. The researchers also listed the knowledge that should be acquired by the teachers to teach the concepts of computer science. In addition, the researchers provided an example of teacher preparation course, and 15 elementary schools' teachers participated in this course. The course focused on developing the students' problem-solving skills before teaching them the use of computer's programs. The study concluded that the effectiveness of the curriculum framework for computer science subject, and the well-prepared and educated teachers will provide an effective computational thinking learning environment for the students. (Charoula Angeli, 2016)

(Budiyanto, 2018) study examined the use of robots to enhance the computational thinking and problem-solving skills for elementary students. The study conducted a literature review based on three different databases and digital libraries. The study collected the impacts of applying computational thinking activities on elementary education. It also discussed the advantage of using educational robotics to improve the students' computational thinking skills.

The results of the conducted literature review stated that the integration between educational robotics and educational thinking in one unit will develop the learning process in all fields. After that, the study discussed the advantages of robotics to improve computational thinking skills. The first advantage is that using robotics will develop the students' problem-solving skills, which will enable them to provide creative solutions to solve problems. Secondly, robotics has a positive impact on students' understanding of STEM subjects. Finally, robotics helps the students to understand the programming concepts. (Budiyanto, 2018)

(Budiyanto, 2018) and (Budiyanto, 2018) studies were reviews on how to integrate computer science subject into elementary curriculum by using robotics, which is out of the objectives of the proposed study.

(Sáez-López, Román-González and Vázquez-Cano, 2016) investigated the use of visual programming language in education. The study targeted 5th and 6th grade students in 107 primary schools in Spain. The study lasted for two academic years to analyse the integration of coding and visual blocks programming in Science and Arts subjects. The researchers conducted a questionnaire and structured observations to analyse the practice of experimental group.

During the conducted pedagogical design, the students were able to create their educational content that was related to their curricular areas. This was happened because the students were motivated, and they felt fun, enthusiasm, and commitment during programming classes. The results of the study stated that the use of visual programming language helps the students to understand the concepts of computational thinking and provides an attractive learning environment that increases the students’ engagement in their classes. At the end, the study highly recommended to apply visual programming language in primary education through a cross-curricular implementation. (Sáez-López, Román-González and Vázquez-Cano, 2016)

The presented study and in this paper and (Sáez-López, Román-González and Vázquez-Cano, 2016) study have the same objectives, targeted the same age group of students, and used visual programming language in teaching the students programming concepts. The difference between them is in the conducted methodologies. The proposed study conducted a qualitative study, while the methodology of (Sáez-López, Román-González and Vázquez-Cano, 2016) study relied on designing a computational thinking curriculum and investigate its’ effects on the students.

2.4 Robotics and STEM education:

This section discusses five studies that aimed to investigate the development on the students’ academic level in STEM subjects after using robotics as an educational tool.

STEM education has been emerged in middle and high schools, but it is stronger in high schools rather than in elementary schools. Students are highly engaged and interested during STEM classes especially while they are using robots. (Kim et al., 2015)

The purpose of (Barak and Assal, 2016) study is exploring the students’ working patterns, achievements, and motivations to learn STEM subjects. The methodology of the study included three phases, which were: practice, problem-solving, and challenge tasks. The study conducted both qualitative and quantitative methods. Qualitative methods included documenting all classes’ activities, interviewing students, and analysing the assignments and final projects submitted by the students. In contrast, the quantitative methods included questionnaires about subject matter exam and attitude about technology and STEM. During the experimental classes, students showed different levels of performance. Some students completed only the basic exercises, others did well with problem-solving tasks, and only few students completed and accommodated complex projects.

The results of (Barak and Assal, 2016) study had proven that robotics classes provided an attractive learning environment for students to study STEM subjects, and they have positive effects on increasing the students' scores and performance in STEM assessments. The mean score of the final exam for the students were 83.67 for girls and 78.56 for boys, and 82.28 for the total class. The scores showed that girls got 70% of the classes' excellent scores compared with the boys. In general, all the students' scores had been increased in STEM subjects after using robotics as an educational tool. Moreover, the success of the robotics classes depends largely on the way of designing and introducing the courses' materials to the students especially the students' assignments during the class. (Barak and Assal, 2016)

(Alshehri, 2019) study planned to create an active learning environment for students in STEM classes. The researcher conducted three case studies and recorded observations about the students' performance and engagement level during STEM classes. He also collected the learners' feedbacks after each case study.

In case 1, the students used robotics in Science and Technology Motorcycle Steering to create movement balance. In case 2, the students used educational robotics in Engineering-solving Dijkstra algorithm. The idea of the case study is to find out the effect of robotics in simplifying the algorithm to help the students in understanding and applying its' concept. (Alshehri, 2019)

In the last case study, the students used robotics in Mathematics. The aim of this case study is to translate real-life problems to mathematical functions. This will help the students to analyse the problem and find a suitable solution to solve it. Case 3 played an important role in developing the students' problem-solving and critical thinking skills. At the end, the researcher summarized all the challenges and implementations in his study. (Alshehri, 2019)

The results of (Alshehri, 2019) study were listing all the learners' feedbacks during the three case studies. The feedbacks were related to the ways of teaching and planning robotics and STEM classes.

(Pauline Mosley, 2016) and (Amy Eguchi, 2017) followed the same methodologies to investigate the students' critical thinking and STEM interest by using educational robotics. (Pauline Mosley, 2016) study targeted six-grade students, while (Amy Eguchi, 2017) study targeted fourth-grade students.

The data set of (Pauline Mosley, 2016) study was 94 students who were divided into two groups, 49 students in experimental group and 45 in control group. All the participants students stated that they do not have any previous experience in using Lego Mindstorms. The methodology of the study connected three important areas in teaching STEM subjects: STEM interests, self-efficiency, and critical thinking. The methodology based on pre-test and post-tests engagement and critical thinking assessments. During the methodology two learning methods were applied: Robotics Cooperative Learning (RCL) and Problem Based Learning (PBL) methods. The researchers conducted t-test to determine if the students' attitude is related to RCL or PBL.

The results showed that the students' scores in RCL post-test were higher than the post-test in PBL. The results supported the research's hypothesis that using robotics as an educational tool will increase the students' interests, engagement, and understanding in STEM subjects. (Pauline Mosley, 2016)

(Kim et al., 2015) study indicated that the knowledge of Science and Math teachers and the applied teaching methods are largely limited to what they remember and what they taught from Science and Math classes when in K-12 schooling. Therefore, STEM teachers need to be more equipped with STEM content knowledge.

The purpose of (Kim et al., 2015) study is to prepare pre-service teachers to be able to integrate hands-on learning with elementary STEM instructions, and to provide them with opportunities to experience with different types of classroom activities. The most important classroom activity integrated with course curriculum is robotics. Elementary school's teachers participated in preparation courses about learning and teaching via robotics. The participants of (Kim et al., 2015) study were sixteen students from two sections of pre-service teacher education course at a university in Southeastern United State. When participants completed all the robotics activities, post-surveys and interviews were conducted with them, and the researchers collected all the lesson plans materials. In addition, all the robotics classes were video recorded, and they were used to analyze the students' engagement. (Kim et al., 2015)

The data was collected from classroom's observations, surveys, interviews, and lesson's plans. Both qualitative and quantitative data analysis were conducted, and all the results indicated that the teachers' engagement was increased in teaching STEM subjects after using robots. The researchers performed t-test to determine if the participants' knowledge in science and technology has changed after participating in robotics activities.

The results of t-test analysis showed that there was no significant change in students' knowledge in science, technology, and engineering, after applying robotics activities. In addition, the teachers stated that their lessons' plans of STEM subjects have been improved in productive directions. All the results of the study indicated that the teachers' and the students' engagement and interests in STEM subjects have been increased after using educational robotics. Regarding to the students' results, the change in their scores before and after participating in robotics classes were not meaningful.

In this section, all the methodologies of the discussed studies that aimed to investigate the effect of using educational robotics as a tool to increase the students' and teachers' engagement and performance in STEM subjects were of the proposed study' scope.

2.6 Teaching robotics for gifted students:

This section discusses four studies about teaching programming for gifted and talented students by using robotics.

(DiMartino, 2017) aimed to start implementing a special robotics programs for gifted students. At the beginning, the researchers conducted a workshop for parents, students, and teachers to introduce the idea of the new program. After that, the teachers participated in a workshop about teaching robotics and programming for gifted students. The robotics' lessons were divided into three parts: beginning, intermediate, and advanced lessons. The teachers then started teaching robotics for gifted students. (DiMartino, 2017) study indicated that the main idea of teaching programming is the curriculum concepts. The adopted robotics curriculum in the study included lessons integrated with Math, Science, Engineering, and Physics subjects, and it focused a lot on developing the students' STEM skills. In addition, the lessons focused on developing the students' programming skills as well as social skills.

(Eguchi, 2016) study discussed the idea of using robotics to foster gifted and talented students' learning to acquire the important skills in 21^{st} century. These skills will create innovators people who will have a positive effect on the future's economy. The study stated that not only using robotics in classes is important, but also the way of teaching and providing information to the students.

(Eguchi, 2016) study presented and explained some effective learning processes that should be followed during robotics classes. The presented strategies in the study focused on improving the students' skills in many fields as well as programming skills.

In addition, (Eguchi, 2016) discussed the results behind following the learning strategies for gifted students on the students' skills and their effects on their society.

(Jennifer Cross, 2016) study described the process for recognizing gifted students in the areas of computational thinking and engineering design. The study targeted middle school's talented students, and it focused on unifying and simplifying the computational thinking teaching models. The proposed teaching frameworks of (Jennifer Cross, 2016) study focused on providing distinct models in engineering design process, the concepts of the system engineering, and the process of design thinking. All these frameworks were provided to the teachers to recognize the computational thinking and engineering design skills of the students.

The researchers conducted a training course for the teachers to help them in evaluating their students' skills. The results of the study indicated that adopting the proposed frameworks helps the students in recognizing their talents and aligning them with their possible future careers. (Jennifer Cross, 2016)

(Tomislav Jagust, 2017) study targeted the gifted and talented students from grades 2 to 4 by conducting workshops for the students as extra-curricular activities. The purpose of the workshops was introducing gifted students to computer programming and robotics and developing their algorithmic, problem-solving, and creativity skills. The researchers observed that the gifted students' skills had been developed significantly. During the workshops, the students provided creative ideas and designs, suggested alternative solutions for a given problems, and expressed their art and music talents through robots and programming tasks. (Tomislav Jagust, 2017)

The results of all the previously discussed studies confirmed that teaching advanced robotics curriculum showed a high progress on gifted students' skills in STEM, problem-solving, and critical thinking. Moreover, the students' innovation and creativity increased significantly. All the pervious discussed studies used robotics to enhance the students' skills which is similar to the proposed study's objectives and methodologies. The difference between them is the targeted group of students. The proposed study in this paper targeted elementary students, while the previous studies targeted only gifted and talented students.

Chapter Three: Methodology

3.1 Participants and course content

The participants in the conducted study were 115 students from grade four who were divided into five sections, in one Private American curriculum school in UAE. The curriculum of grade 4 in term 2 was building and programming robots. The used application and robots' kits were WeDo 2.0 Lego education. The students need to install WeDo 2.0 application in their iPads to program the built robot and connect the program with the robot via Bluetooth.

The applied programming tool is based on programming blocks. Each programming block has specific image and color that describe the function of the block. The programming blocks cover multiple programming concepts; such as: if statement, loop, input and output variables of the programming functions, and movement functions.

Lego Education WeDo 2.0 was constructed to support students and motivate their interests in learning science and engineering related subjects. The students learn by asking questions and solving problems related to their real life or to a topic integrated with their curriculum. WeDo 2.0 includes different projects which are divided into three types: getting started, guided, and open projects. Each project is divided into four phases: explore, create, test, and share phases. [1]

In the explore phase, the teacher introduces a scientific question, or an engineering problem to the students, and the students should suggest possible solutions to solve the problems.

In the create phase, the students build and program a Lego model, while during the test phase, the students are given challenging questions to be solved.

[1] https://education.lego.com/en-us/support/wedo-2/teacher-guides

In share phase, the students use the integrated documentation tool to present and explain their solutions to their friends. [2]

3.2 Research procedure

The students were taught WeDo curriculum for two months and three weeks. Each section in grade four had two block ICT periods per week. During the teaching time, multiple assessments, observations, and challenges were conducted with the students. In addition, some students presented different robots in STEAM (Science, Technology, Engineering, Art, and Math) Day. The programming curriculum covered different robots' ideas and programming concepts. The students were required to complete one project per week. Each project had a specific idea and objective.

The WeDo classes were taught within a specific methodology. At the beginning of the class, the lesson's objectives were explained to the students. Secondly, the teacher showed the students a video about the project's problem and explained how this problem affects our life. This was conducted to provide the students with a comprehensive information about the project's objectives and problem. After that, the teacher discussed the project's problem with the students and asked them to suggest some ideas to solve the explained problem. The aim of the discussion time during the class is to improve the students' critical thinking and problem-solving skills. Fourthly, the teacher explained the robot's building instructions and programming concepts to the students. At the end, the students built and programmed the robot and documented their findings.

[2] https://education.lego.com/en-us/support/wedo-2/teacher-guides

The students were divided into groups of two students, and they were distributed based on their academic levels and personalities. Finally, the teacher gave the students a challenging programming question to be solve.

The conducted projects by the students per week will be explained as following.

In the first week, the teacher introduced the curriculum plan and objectives to the students. The teacher also explained the classroom rules that should be followed by the students during the robot's building and programming processes. In addition, the students were asked to build a simple robot to get overall ideas about using the kit and building the robot.

In the second week, the students were required to build and program a robot that can move forward and backward. The students should specify the speed limit and movement direction in the robot's programming.

The challenging question was: "Program your robot to move with speed limit 25 forward, wait for 5 seconds, then move with speed limit 20 backward, and at the end it will stop".

The required robot in the third week was a small robot that has a motion sensor. The aim of this robot is detecting objects in different places that are difficult for people to reach; such as: caves, deserts, deep oceans, and space. During this lesson, the teacher explained the input and output processes between the sensor and the robot's hub. The programming steps of this robot covered "if-statement" programming concept, and they are as following:

I. The robot should move with speed limit 8 forward
II. The robot will wait for a message from the sensor
III. If the sensor detects an object in front of the robot, it will send a message to the robot's hub about the detected object
IV. At the end, the robot's hub will ask the motor to stop, and it will generate sound. The sound is an alert to inform the user that the object was detected.

The fourth project was building and programming a messaging hand. The idea of this project is building a robot that has a tilt sensor to be used in sending messages. The tilt sensor is able to specify the movement directions. The teacher also explained the input and output processes of this robot, but the results differ from the results of the previous robot. In the fourth project, "if-statement" and loop programming concepts were explained to the students.

The robot's programming steps are as following:

I. If the messaging arm is moved forward, the hub's light color will be changed, and "Forward" message will be displayed in the iPad.

II. If the messaging arm is moved backward, the hub's light color will be switched off, and "Backward" message will be displayed in the iPad

III. This process will be repeated for infinite number of times

The challenging question was specifying the number of process repeating times. For example, repeat the messaging process for only five times.

After teaching WeDo curriculum for one month, the teacher conducted a quiz to assess the students' understanding level in programming. The quiz had two questions, one theory and one practical question. The theory question was about the programming blocks functions, while the practical question was a programming question.

After that, the students started with the fifth project which was an earthquake simulator. The aim of this project is to investigate how buildings can be designed to be safer and stronger against earthquakes. The programming concepts of the robot are as following:

I. At the beginning, a message "0" will be displayed in the iPad. Number "0" is the earthquake magnitude before the robot starts working

II. Number "0" will be incremented 8 times

III. The motor speed should be similar to the displayed message in the iPad
IV. The displayed number in the iPad will be an input to the motor power block
V. After each rotation, the robot will wait for 2 seconds, then the motor's speed will be incremented by 1

The challenging question was: "Design and build a building that can withstand against more than 8 earthquake magnitude".

In the seventh week, the teacher started with evaluating the students' programming skills by conducting in-class programming assessments. The in-class assessments continued for three weeks. The researcher's observations during the assessment and the students' results and analysis will be discussed in the following chapter.

After completing the assessments, the students built two more robots, pulling and speed robots. Each robot was built in a week.

In week eight, the students built a robot that can be used to carry heavy things. The aim of this robot is to explore types of forces, and how can objects move by applying balanced and unbalanced forces. [3] The programming concepts of the robot are as following:

I. At the beginning, the robot will display "3" then "2" then "1" messages respectively.
II. Then the robot will move with speed limit 10 forward
III. The robot's movement will continue for two seconds

The construction of the robot allows the robot to apply balanced and unbalanced forces during movement to move heavy objects. The teacher did not give the students a challenging

[3] https://education.lego.com/en-us/support/wedo-2/teacher-guides

question due the lack of time because the robot's building steps were difficult, and they took around 45 minutes.

The last robot was race car robot. In this robot the students will explore the features of the race car and investigate the factors that increase its' speed.[4] The programming steps of the race car robot are as following:

I. At the beginning, the robot will display "0" message. This number expresses the initial speed of the car.

II. The robot will wait for the motion sensor to detect the solar energy.

III. If the motion sensor detects the light, the robot will move with speed limit 10 forward. During the movement process, the speed of the robot will be increased. This will happen by incrementing the initial speed with 1.

IV. If the motion sensor detects another object, it will stop.

In this robot, the students used flash light as a sunlight because the motion sensor does not have the ability to recognize the solar energy.

The challenging question was "Modify the robot's program in a way that allows the robot to move faster than before and to increase its' speed more"

In the last week of teaching robotics, the teacher conducted the last programming assessment to evaluate the students' attainment and progress in programming. The results and analysis of last assessment will be also discussed in the following chapter.

[4] https://education.lego.com/en-us/support/wedo-2/teacher-guides

3.3 Research Instruments

The data collection methods that were followed in this study are recording the observations during the classes, a questionnaire distributed to the students, and multiple programming assessments. The questions in the questionnaire covered two main ideas, which were:

I. A questionnaire adapted from a validated questionnaire from Robotics and GPS/GIS in 4-H project about the students' interest level [5]

   The questions of the questionnaire were be modified to suit WeDo classes activities.

II. The effect of teaching robotics on the students' interest during robotics classes, students' problem-solving, and communication and collaboration skills

III. Multiple assessments to measure the students' robotics and coding knowledge

Chapter Four: Results and analysis:

In this chapter, the results of the study will be presented and analysed. The results of the study were collected from the observations, multiple programming assessments, and the questionnaire which was conducted at the end of the study. The observations were recorded during WeDo classes, programming assessments, and filling the questionnaire times. In

[5] https://oerl.sri.com/instruments/ITEST/interviews/studsurv/instrNew2.html

addition, the students' strengths and weaknesses in programming will be discussed and analysed.

4.1 Results and analysis of teaching robotics:

This chapter discusses the researcher's observations and analysis of robotics classes to answer the research's questions, as well as the challenges of teaching programming for elementary students. The research questions will be answered based on the results of the observations and questionnaire analysis.

4.1.1 Observations and analysis of robotics classes:

I. RQ1: How does engagement in the robotics activity influence the students' interest and self-efficacy during robotics classes?

During the teaching period, the researcher observed the students and wrote comments about the students' performance in all the conducted projects. The researcher's observations and comments are discussed in the following table.

Table 1. Researcher's observations and comments

Project's name	Students' interest and engagements level	Students' performance in building the robot	Students' performance in programming the robot	Students' performance in solving challenge questions
Milo's the science rover	• All the students were engaged and showed a high level of interest during the explanation and discussion time in the lesson. • During the explanation time, all the students were listening to their teacher without interrupting	• Most of the students faced difficulties in finding the Lego bricks in the kit and deal with WeDo application. • The students took a lot of time to build the first robot, and they need a lot of help and direction in building the	• Most of the students faced difficulties in dealing with the programming blocks, but at the same time they understood their functions well. • Although the teacher explained the steps to connect	• Few students only had time to solve the challenging question, but none of them could solve the challenging question.

	him. • During the discussion time, only few students participated and provided some ideas and opinions to solve the proposed problem in the lesson. • At the end of the lesson, the students gave positive feedback about their interest during the lesson.	robot. • At the end of the period, all the students built the required robot without any mistake.	the robot with the iPad via Bluetooth, all the students needed help to connect them practically. • At the end of the class, all the students programmed the robot without any mistake.	
Milo's motion sensor	• The students' interest level had increased in comparing with the previous project. • Most of the students participated with their teacher and gave some solutions to the proposed problem in the lesson.	• The robot has the same building's instructions as the previous robot with some additions; such as: the sensor • The teacher did need to explain the robot's building steps because the students showed their abilities to build the robot without any help. • All the students built the robot without any mistake, but few of them needed help in finding some Lego bricks in the kit. • Almost all the students built the	• All the students were able to deal with the programming blocks without any help from their teacher. • The students faced difficulties in understanding if-statement programming concept • Few students understood the input and output processes between the sensor and the robot's motor.	• The teacher did not give the students a challenging question due to lack of time. This happens because the teacher spent a lot of time in explaining the robot's programming.

		robot within the required time for building the robot, but few groups needed extra time to complete building their robot.		
Milo's messaging arm	• The idea of the project was not attractive to most of the students, and they asked their teacher to build another robot.	• All the students built the robot and connect it with the iPad without any help. • All the students took the same time to build the robot, and they built it within the required building time.	• Most of the students understood the idea of if-statement, and input and output processes in the robot. • All the students understood the loop programming concept. • The understanding level of the programming concepts was clear and observed through the students' participations during the programming explanation and through their answers to the teacher's questions. • Most of the students changed the	• Few students solved the challenging questions, and they showed their ability to solve the question directly after asking the question by the teacher. • The remaining students tried to solve the challenging question with multiple ways, but they could not achieve the challenge.

			output results of the programming in a way that met their wants.	
Robust Structure	• The robot's idea was so attractive to the students, and most of them participated with the teacher in great manner. • The students' interest level was high, and their willing and enthusiasm to start building the robot was observed	• The robot's building steps were more difficult than the previous robots, but all the students built the robot without any mistake and in timely manner. • All the students shared the building steps with their partners in the group equally. • Few students refuse to share the building's steps, and they asked their teacher to build the robot alone.	• The teacher needed around 20 minutes in all grades four sections to explain the programming of the robot. • Few students in every section understood the idea of incrementing the input variable and how to save and present the output variable.	• All the students showed a high interest level to solve the challenging question. • Most of the students achieved the challenge in multiple ways, and they were able to conclude the main important features to build and design strong buildings.
Pulling	• All the students liked the final shape of the robot, and they were highly encouraged to build the robot. • The idea of the robot was attractive to the students, and all the students were	• The building' steps of the robot were difficult for the students to complete. • Many groups did mistakes and need help in building the robot. • Some students refused to	• The covered programming concepts were easy for the students to understand. • All the students participated with their teacher during the programming'	• The teacher could not give the students a challenging question due to lack of time because the students took a lot of time in building the robot.

	enthusiastic to start building and programming the robot.	complete building the robot. • Few students could complete building the robot without any help and within the time. • The students showed their disappointment because they could not complete building the robot.	explanation time.	
Speed	• All the students especially the boys showed their interest to build the robot • The students had previous knowledge about the solar energy, so they participated with their teacher very well.	• The building' steps of the robot were easy for the students to complete. • Therefore, the students asked their teacher to build more complex robot.	• The programming of the robot had the same concepts as the previous robot. • Therefore, the number of the students who understood the programming concepts had increased.	• The teacher asked the students to modify the robot's programming as a challenge for them, but few students could apply the required modifications. • The modifications that all the students applied were regarding to robot's movement, if-statement, and loop programming concepts. • The weaknesses of the students were in modifying input variable incrementing.

After three weeks of teaching robotics, almost all the students mastered the correct way to use WeDo application and deal with the WeDo kit. In addition, the students were able to complete building the robot without any help from their teacher. Therefore, some students refused sharing the robot's building steps with their friends in the group, and they asked their teacher to build their robot alone. This indicates how students like WeDo classes and they enjoy their time in building and programming the robot. On the other hand, some students asked their teacher to change their group's partner with other students. When they asked about the reason, they said that they want to share building the robot with their best friend.

Moreover, some students asked their teacher how they can buy the WeDo kit, and after two weeks they informed their teacher that they already bought the kit. One student told the teacher that she asked her mom to buy the WeDo kit as a gift for her excellence in her studies. In addition, the idea of the project is one of the most important reason to increase the students' engagement level during the robotics classes. When the topic of the lesson is integrated with the students' curriculum of other subjects, the students were more engaged and able to participate with their teacher.

Moreover, the students' feedbacks at the end of each WeDo class showed how enjoyed were the students during robotics classes. Almost all the students gave positive feedback at the end of robotics classes; such as: "We enjoy our time today", "We love robots", "We want to study robots every day", "This day is our best day", "Can we build another robot today?"

The last indication about the students' interest level during robotics classes is the attendance percentage, which was highly decreased in the week days that have robotics classes.

The percentage of the students' absence during WeDo classes did almost not exist. After two weeks of teaching robotics, the attendance records of the students showed that the percentage of the students who usually be absent or came late to the school without excuses during the weekdays, has been decreased during the weekdays that have robotics classes. Moreover, the students informed the teacher before one day of the robotics class that they will not be absent tomorrow.

All the previous cases showed the high interest and engagement levels of the students during robotics classes.

4.1.2 The challenges of teaching programming:

II. RQ2: What are the challenges in teaching robotics and programming for elementary students?

The most challenging part for the teacher in the lesson is creating an attractive learning environment to explains the lesson's problem and encourage the students to get active participations to suggest solutions to solve the problem. Presenting a video and the discussion time about the problem helped the teacher a lot in explaining the lesson's objectives to the students, and it helped the students to accommodate the robot's main idea. The students were free to share their ideas, opinions, and ask questions during the discussion time, and it took around 15 minutes from the lesson time. The discussion time helped the students to provide innovative ideas and solutions to solve the proposed problem.

The second challenge that faced the teacher is setting the suitable lesson plan about the correct way to teach programming. The idea of teaching programming for elementary students is simplifying the programming concepts to the students in a way that helps them to understand how the information is processed between the robot and its' programming.

The following strategies helped the teacher in teaching and simplifying the programming concepts to the students.

Firstly, the teacher taught only one programming concept per week. In the following week, he taught new programming concept as well as the taught programming concept in the previous week.

Secondly, he divided the whole program into small programs, and explains each part alone.

Thirdly, he showed a video about the desired robot that shows the result of the programming. Finally, relying on programming blocks helps the students to understand the idea behind each programming concept. This is because the programming blocks are easy to use, and each block has a distinguished color and image that clarify the programming concept. All the previous steps help the teacher in teaching programming as well as the students in accommodating the programming concepts.

The last challenge in teaching programming is time management. The teacher faced difficulties in encouraging the students to spend more time in programming the robot rather than building. Most of the students focused on building the robot rather than programming which is the aim of the course. The teacher followed some strategies to overcome this problem by giving the students challenging questions and allowing them to freely modify the program. The challenging questions gave the students a chance to explore and understand new programming concepts, while the freely programming modifications increased their skills in using WeDo application.

4.2 Results and analysis of the questionnaire:

Descriptive analysis conducted to analyse the collected data from WeDo Classes questionnaire as well as the recorded observations during filling the questionnaire by the researcher. The data set of the proposed study was 115 fourth grade students. Three students were absent during the questionnaire time, therefore 112 students participated to fill the survey, 52% male students, and 48% female students. The survey's questions cover four main points: the students' personal

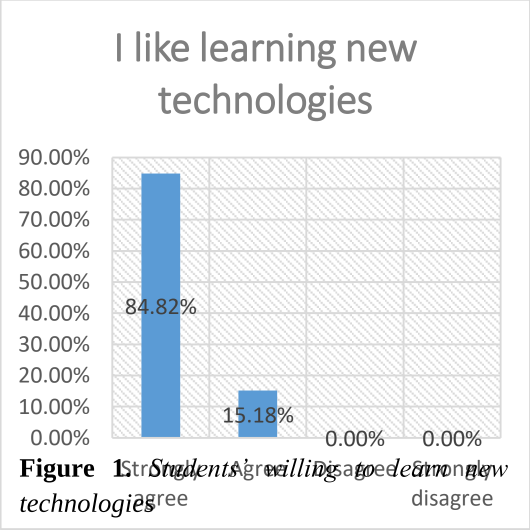


Figure 1. *Students' willing to learn new technologies*

information, the students' engagement and interest levels during robotics classes, the effect of robotics classes on students' problem-solving skills, and the students willing to work in teams during robotics classes.

The first three questions were about students' personal information; their gender, ages, and nationalities .71% of the students were 10 years old, 21% were 9 years old, and the lowest percentage from the students were 11 years old. Most of the students were from United Arab Emirates, were 17% of the students were from Asia, Africa, Middle East, and other countries. The following 9 questions are about the students' interest level during WeDo classes which will answer also the first research question.

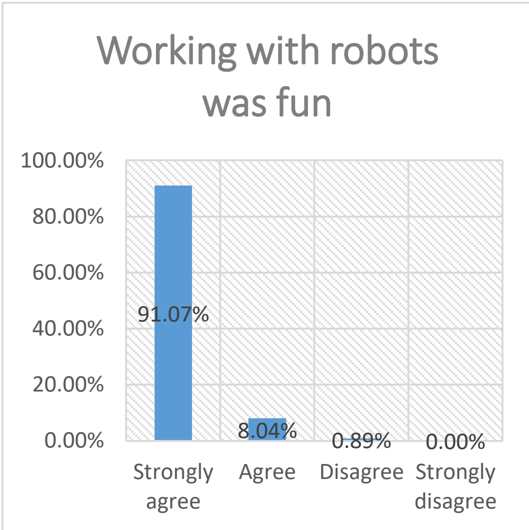


Figure 2. *Students' interest level during robotics classes*

III. RQ1: How does engagement in the robotics activity influence the students' interest and self-efficacy during robotics classes?

The questions aimed to investigate the students' willing to study new information by using technology, and their engagement level during robotics classes. Regarding to the questionnaire's results, all the students agreed that they enjoy learning new technology. Few students (7.14%) showed that they were not sure that they can master robotics skills, and

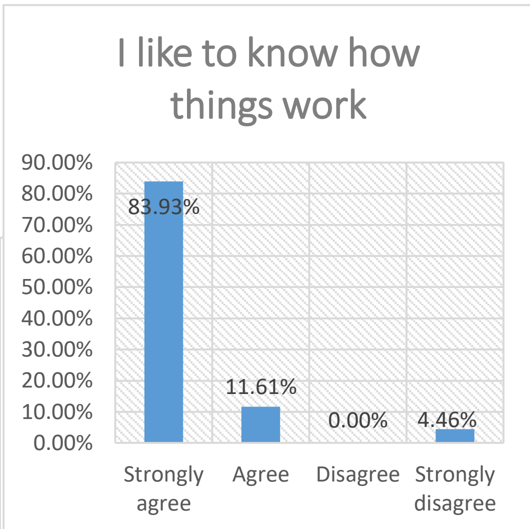
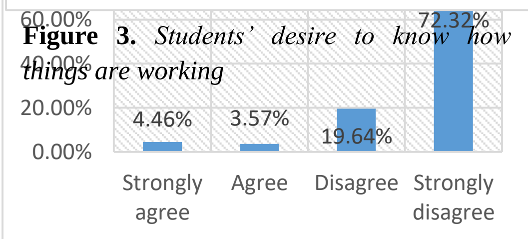


Figure 3. *Students' desire to know how things are working*



only one student mentioned that working with robotics was not fun.

The high percentage of the students who prefer learning new technologies, and who had fun during robotics classes, this shows how much students like robotics classes, and enjoy their time during building and programming robots. This was also observed from the students' feedback and attendance during robotics classes. All the questionnaire's results affirm how much the students like and enjoy their time during robotics classes.

The fifth question in the survey was about the way students prefer to study new information, 96% of the students prefer experiments and doing projects during learning, and only 4 students prefer the traditional learning methods. Questions 6 and 7 aimed to investigate the students' feelings toward building robotics even if they do not like what they are doing, or if the robot is difficult. 87.50% of the students stated that they will complete building the robot, even if they feel la zy or bored, while only 12.50% of the students stated that they will stop before complete building the required robot. 94.64% of the students prefer working with hard robotics activities even if they do not like what they are doing, while only 5.36% of the students was the most important thing for them is how attractive is the robot. Questions 8 and 9 investigate the students' willing to work with difficult robots. The results showed that

Figure 4. *Students' interests in building difficult robots*

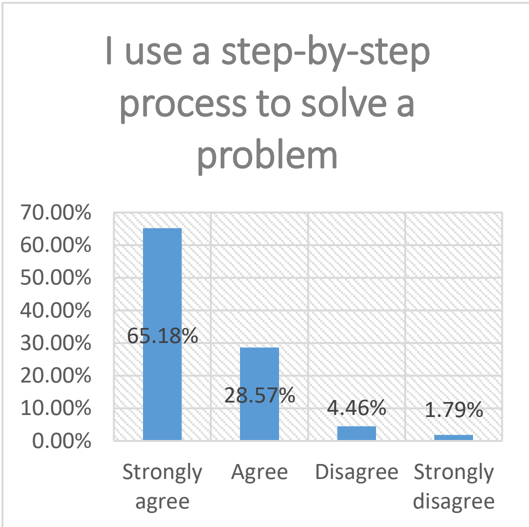


Figure 5. *Students' strategies in solving problems*

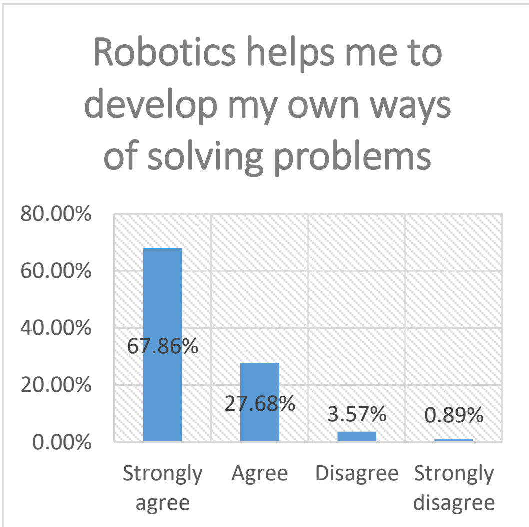


Figure 6. *Robotics' effect on students' problem-solving skills*

more than 91% of the students prefer working with difficult robots and solving difficult programming questions rather than working with easy robots.

The students showed their high interest in building complex and difficult robots, which ensures the students' high engagement level during robotics classes. This indicates that the students want to spend more time in building and programming robots. The last question was about the students' desire to know how things are working. 107 students mentioned that they like to know how things work, while only 5 students do not have this desire. This was also observed during WeDo classes from their questions during the discussion time in the classes.

The following six questions aimed to investigate the effect of WeDo classes on students' problem solving's skills which will answer the fourth research question.

IV. RQ3: How does teaching robotics affect the students' problem solving and critical thinking skills?

In this phase, the researcher explained each question and connected it with the followed learning process during WeDo classes. Questions 11, 12, 13, and 14 were about the way the students follow to solve any problem. All the results showed positive effects on students' problem solving' skills. 96% of the students agreed that the followed learning process during robotics classes helped them to develop their problem solving' skills, but only 5 students stated that WeDo classes had no effect on their problem solving's skills. Almost 93% of the students followed the same steps in solving any problem by putting a pl an before solving the problem, breaking down the problem into smaller problems, and

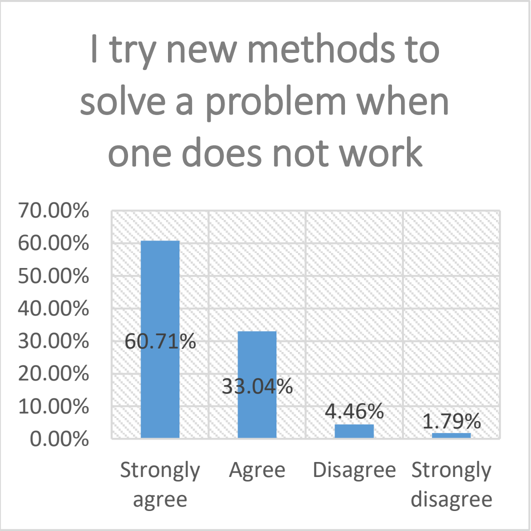


Figure 7. *Students' strategies to solve challenging problems*

using step by step process to solve it.

Question 15 was about the students' ability to make a decision based on proven information, 103 students agreed that they can draw a conclusion based on evidence. The students' ability to make a decision was also observed by the students' educator. During robotics classes, the teacher shows the students a video about one real-life problem. The video provides some information and evidences about the problem. After that, the teacher discussed the problem with the students and asked them to suggest some solutions to solve the problem by using robots.

In the first two lessons, few students can provide solutions for the proposed problem, but at the end of WeDo classes most of the students were able to suggest solutions for any given problem.

The last question was about the students' ability to suggest alternative solutions to solve a problem if one solution does not work. Most of the students (94%) stated that they are able to try new methods to solve a problem, while only 7 students said that they do not have this skill. This was also observed by the teacher when he asked the students to solve a challenging question. At the beginning of the course, two or three groups only who could to solve the challenging questions, although all the students tried to solve it. This was because most of the groups tried only method to solve the challenging question. When the proposed method from the students did not work, the students gave up, and they refused to try another method. However, at the end of WeDo classes most groups were able to solve any given challenging question, and some of them provided more than way to solve it.

The teacher's and researcher's observations and the questionnaire's results indicate that robotics classes had increased the students' problem-solving skills. Robotics classes increased the students’ abilities to understand real-life problems and their effects on the earth and society. As a result of the discussion time about the problems during robotics classes, students were able to provide multiple solutions to the proposed problems. This indicates that WeDo classes increased the students’ imagination, innovation, and cognitive skills.

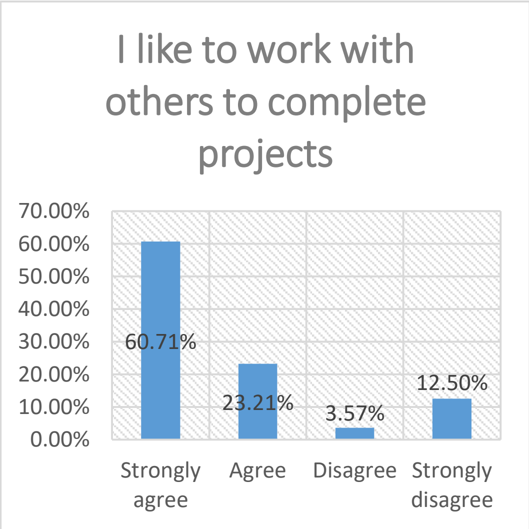


Figure 8. *Students’ preference to work in groups*

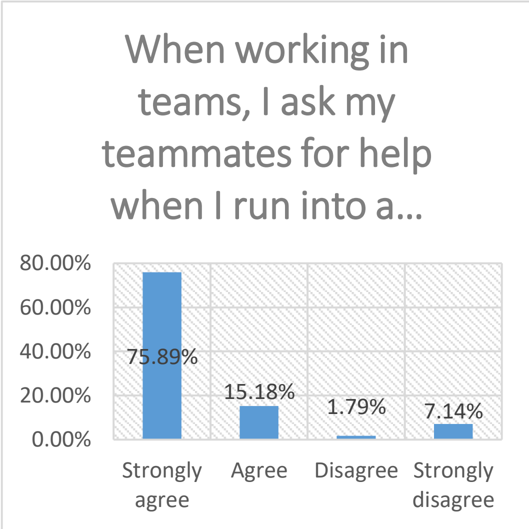


Figure 9. *Students’ teamwork skills*

The last three questions in the survey were about the students’ willing and interest level to work in groups to complete the robotics’ projects. The results showed that almost 93% of the students can deal with their teammates during building and programming the robot. The results of question 18 showed that 83.93% of the students prefer working with others to complete projects, while 16.07% of the students prefer working alone. The researcher asked the students about the reason behind their preference to work alone, they said that they like building and programming robots a lot, and they want to complete each single step by themselves. Their answers ensure the questionnaire’s results and the researcher’s observations about the students’ interest level during WeDo classes. On the other side, most of the students showed their preference to work in groups, and some of them asked their teacher to put them with their friends in one group. Most of the students showed a great integration with their friends during robotics classes.

4.3 Results and analysis of the assessments results:

The second data collection method was multiple programming assessments. The assessments were conducted during the methodology time, and the results were checked, and analysed. During the assessments' time, the teacher explained the programming questions to the students, and he gave them direct feedback about their mistakes. The researcher observed the students and wrote notes about the students' performance, results, strengths, and weakness in the programming assessments.

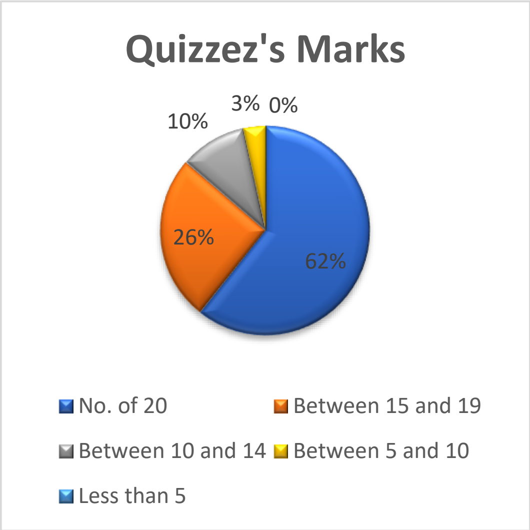


Figure 10. *Students' quizzes marks*

After three weeks of teaching robotics, the teacher conducted a programming quiz which covered the basic programming concepts. The questions in the quiz assessed the students' understanding about the programming functions of robot's movement, movement's directions, and time management. The programming quiz was out of 20 marks, and it includes two questions, theory and practical questions. Each question was out of ten marks. The students' results in the quizzes were ranging from excellent to good levels. As shown in Fig. 10, 62% of the students got full mark in the quiz, and only 3% of them got less than 5 marks.

The researcher observed that 75% of the students completed the quiz within 10 minutes, while the others need maximum 20 minutes to complete the quiz. Most of the students' mistakes were in theory question. The common mistakes between the students in the practical question were in the robot's movement direction and time mangement. On the other hand, all the students were able to program the robot's movement and speed limit. According to the quizes' results, the teacher focused on the students' weaknesses during the explanation of the next robotics lessons.

After six weeks of teaching robotics, the teacher conducted an in-class programming assessments which covered more advanced programming concepts than the covered concepts in the quiz. The assessment took three weeks to be completed, and it included five programming questions, each question was out of ten marks. The covered programming concepts were if-statement, loop, input and output programming variables, and math functions. In addition, the covered programming questions in the quiz were also included in the in-class assessment. As shown in Fig. 11, there were no students who got less than 30 marks which means there was no failur in the second programming assessment.

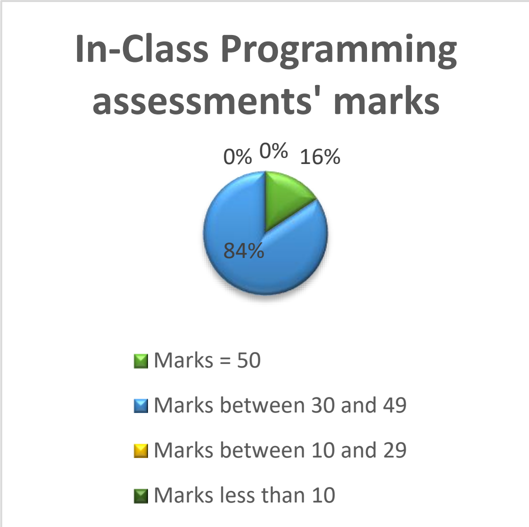


Figure 11. *Students' in-class programming assessment marks*

Question 1 in the assessment included programming concepts of displaying information and robots movement. The students who got less than 10 marks were only 17 students, and they lost either one or two marks. They lost their marks because they needed minimal help in selecting the correct programming block for displaying information.

Question 2 included if-statement, displaying information, and input and output programming variables. All the students mastered if-statement, displaying information, and output programming variables. The common mistake between all the students who lost marks was in identifying the input programming variables, which were the correct sensor and the sensor's direction in the if-statement. The percentage of the students who got full mark in question 2 was the lowest percentage compared with the results of the other programming questions.

Question 3 included if-statement, movement functions, time management, and input and output programming variables. All the students who lost marks had the same mistake which was identifying the input programming variable. The required input variables were the motion sensor and the sensor's condition.

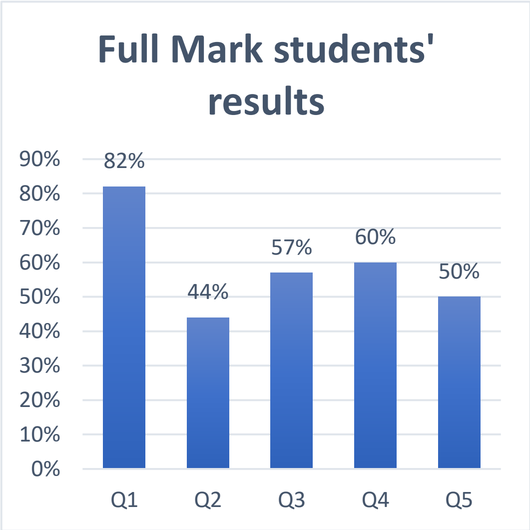


Figure 12. *Full Mark students'*

Question 4 included all the previous covered programming concepts as well as loop programming function. 60% of the students got full mark in question 4, and the students who lost marks had the same mistake which was identifying the input variable of the if-statement.

Question 5 included loop, Math functions, displaying information, and incrementing variables programming concepts. All the students mastered the covered programming concepts in question 5 except displaying the result of the addition process, which needs displaying information and saving programming blocks. All the students did the same mistake in selecting the correct block for saving the mathematical problem's result. The percentages of the students who got full marks in the in-class programming assessment were displayed in figure 12.

According to the researcher observations and the students' results in the assessment, all the were able to solve the questions that include the following programming concepts which are:

if-statement, loop, movement functions, and output programming variable. On the other hand, all the students who who lost marks had the same weaknesses in identifying the input programming variables.

During the assessment time, all the students needed help and directions to solve the questions, while the number of students who need help decreased over the assessment time. This indicates that the practicing time in WeDo application has a great effect on the students' performance. The students were more familiar with the application's blocks after solving the second programming question. The practicing time on WeDo application during the assessment is different from the practicing time during the robotics lessons. The resaecher found that the students need to practice programming without using robots to be able to solve different programming questions. The robot's responses help the students to modify the programming based on the required situation and to figure out their mistakes in the programming.

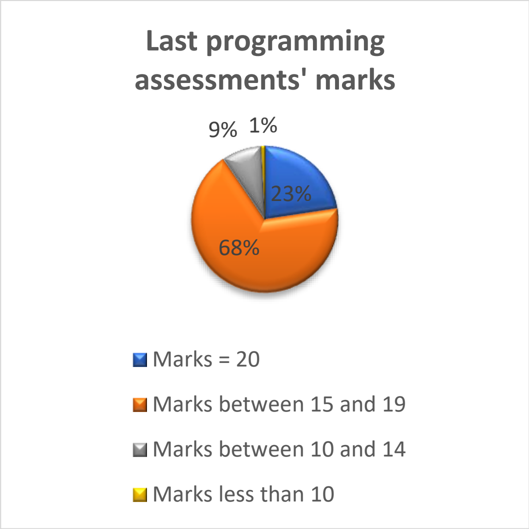


Figure 13. *Students' last programming assessment marks*

After the last week of teaching robotics, the teacher conducted another in-class programming assessment which was out of 20 marks. The aim of the last assessment is to evaluate the students' programming skills after building and programming multiple robots, and after conducting different programming assessment. The last assessment covered all the taught programming concepts during robotics classes, and it focused on the students' weaknesses in programming. According to the last assessments' results, only one student failed in the last assessment, and 91% of the students got marks between 15 and 20. (see Fig. 13)

In the last assessment, the number of the students who needed help and direction had decreased. Most of the students completed the assessment within 15 minutes, and they got high marks. The students' their abilities to use the program easily, and their skills in solving the programming questions were highly visible during the last assessment.

The practicing time on WeDo application has a great effect on students’ abilities in solving the programming questions and their results. In addition, the students were more familiar with the questions style after conducting the quiz and the in-class assessment, and this resulted in their ability to understand and solve the questions in the last assessment in a better way.

4.4 Discussion on students’ weaknesses and strengths:

This section will discuss and analyze the strengths and weaknesses of the students in programming skills after teaching them robotics and conducting multiple assessments for nine weeks. This section will answer the research’s question.

V. RQ4: Is teaching robotics a useful tool to teach programming for elementary students?

One of the most important strengths of students’ programming skills that has been accomplished is the students’ ability to program a robot that can achieve multiple tasks at the same time. The students were able to give the robot multiple functions to achieve, and they can modify any program based on their wants.

The students understood and accommodate the following programming concepts: if-statement, robot’s movement functions, and output programming variables. There were some exceptions from the students who needed help in programming the robot and applying the previous mentioned programming concepts.

On the other hand, most of the students faced difficulties in understanding the input programming variables and applying Math functions and showing their results. Most of the students could not select and modify the correct input variable for different programming functions. In this case, the students are divided into two groups. The first group is that all the students were able to specify the speed limit, sound, waiting time and incrementing input variable of the robot. The second group is that most of the students were not able to select the correct sensor and it case to be an input for any if-statement. In addition, they also could not select the correct programming function that restores the mathematical programming function and shows it result. Few students mastered how to apply the mathematical problems and select the input sensors correctly. All these students were academically high achievers students.

After studying all the data and the results of the study, we found that the main important reasons that help the students to understand the programming concepts are time, integration with real-life topics, pictures and icons, and familiarity with the programming questions.

Firstly, the students need at least three weeks to understand any new programming concept. This was observed from the students' assessments results and from the students' performance during robotics classes. All the programming concepts that the students understand and know how to apply them, were taught for the students for three of four weeks.

All the programming blocks have images and signals that clarify their functions. This helps the students to understand and memorize the role of each programming concepts. The colours of the programming blocks also help the students to distinguish between the roles of the programming blocks. For example: green programming blocks are related to the robot's movement functions, while red blocks are related to the results' displaying and mathematical functions.

Integrating the idea and the objectives of the robot with real-life topics plays an important role to attract the students during robotics classes and understand the programming concepts. It is known that studying by doing experiments and using visual materials help student to understand and memorise the information very well. This was also mentioned from the students' responses in the questionnaire.

Familiarity with the programming questions is so important for the elementary students to get high marks in their assessments. The students' performance in the last assessment was better than their performance in the in-class assessment. When the students get used with the style of the programming questions, they perform well and do not need help and guidance during the assessment. The students need to practice how to solve the programming questions without using the robot for many times. This will help the students to focus on only the programming.

Chapter Five: Conclusion:

Teaching programming is a challenging task for the teachers, it is difficult for the students to understand the programming concepts especially for the elementary students. Many educational programming tools are available to teach programming. One of the most popular programming tools is programming blocks that is integrated with building and programming robots. The proposed conducted study has four objectives. Firstly, it aimed to investigate if the use of educational robotics will be an effective tool to increase the students' engagement and interest levels during classes. Secondly, the study aimed to find out the challenging in teaching programming for elementary students and suggests some solutions to overcome the challenges.

The third objective was investigating the effects of teaching robotics on students' problem-solving and critical thinking skills. The last objective was determining if educational robotics is a suitable tool to teach programming for elementary students.

A qualitative study conducted to fulfil the objectives of the study. The research's instruments were observations during the teaching and assessments classes, multiple choice questionnaire, and multiple programming assessments.

All the students showed a high engagement level in robotics classes, and they expressed their feelings and excitements to their teacher during the course. The results of the study stated that educational robotics is an effective tool to develop the students' skills in many aspects: critical thinking, problem solving, and programming skills. Most of the programming concepts were easy for the students to understand, while few concepts require more efforts and time to be accommodated by students.

The challenges of teaching programming for elementary students are setting the session' plan, encouraging the students to participate and during the classes, and time management. Additionally, teaching programming for the students in a suitable way that helps them to understand and accommodate the programming concepts. The results showed that the students need at least three weeks of teaching to understand one programming concept, and the students' familiarity with the assessments' questions affect the students' performance and scores in the assessments in a positive way.

The proposed study can be developed by conducting quantitative methods that include control group to investigate the effectiveness of the robotics in teaching programming, which will be as a future work for this study.

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Appendix 1

Table 2. We are interested to know your attitude toward studying robotics.

Part 1: Students' interest and engagement level

		Strongly Agree	Agree	Disagree	Strongly Disagree
1.	I like learning new technologies				
2.	I am certain that I can master robotics skills.				
3.	Working with robots was fun.				
4.	I enjoy learning when I get to do things.				
5.	If I get lazy or bored during the robotics' activities, I am likely to quit before I finish what I had planned to do.				
6.	I will work hard on robotics' activities even when I don't like what we are doing.				
7.	If the robotics' activities get difficult, I will likely give up or do something else.				

Part 2: Students' self-efficacy related robotics

		Strongly Agree	Agree	Disagree	Strongly Disagree
8.	I like to know how things work.				
9.	I enjoy working on a difficult problem.				
10.	Robotics helps me to develop my own ways of solving problems.				
11.	I use a step-by-step process to solve a problem.				
12.	I put a plan before I start to solve any problem.				
13.	I can draw a valid conclusion based on evidence.				
14.	I try new methods to solve a problem when one does not work.				
15.	To solve a complex problem, I usually break it down into smaller steps.				

Part 3: Students' ability to work collaboratively

		Strongly Agree	Agree	Disagree	Strongly Disagree
16.	I often try to explain activities to my teammates or classmates.				
17.	I like to work with others to complete projects.				
18.	When working in teams, I ask my teammates for help when I run into a problem or don't understand something				

Appendix 2:

Survey's results

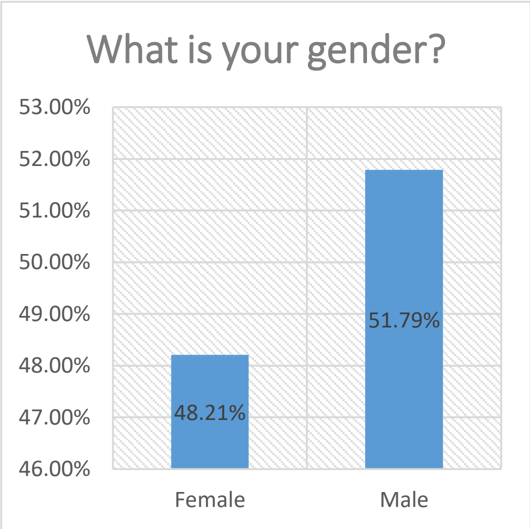


Figure 2. *Students' gender*

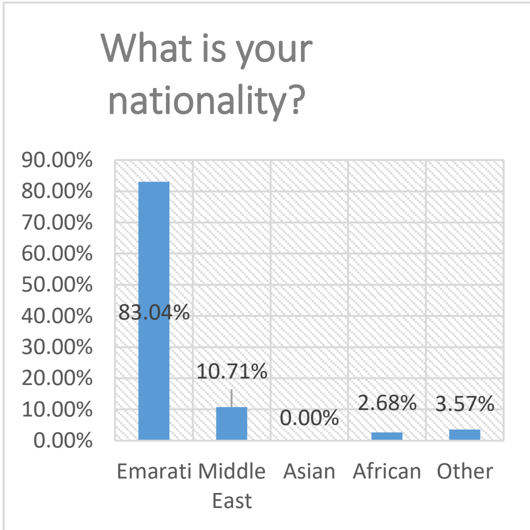


Figure 2. *Students' nationalities*

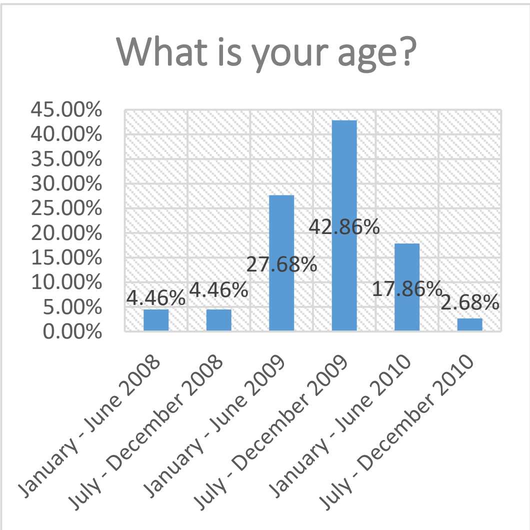


Figure 3. *Students' ages*

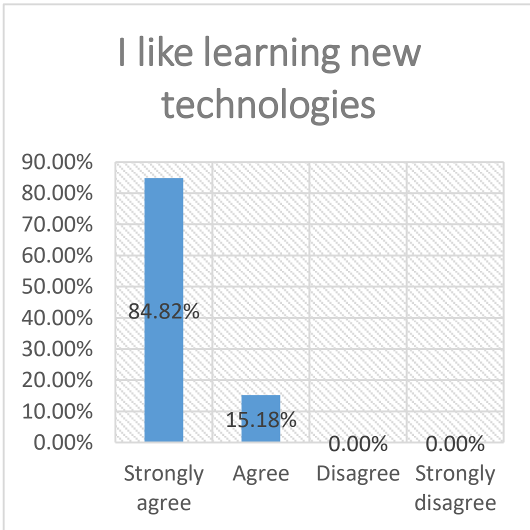


Figure 4. *Students' willing to learn new technologies*

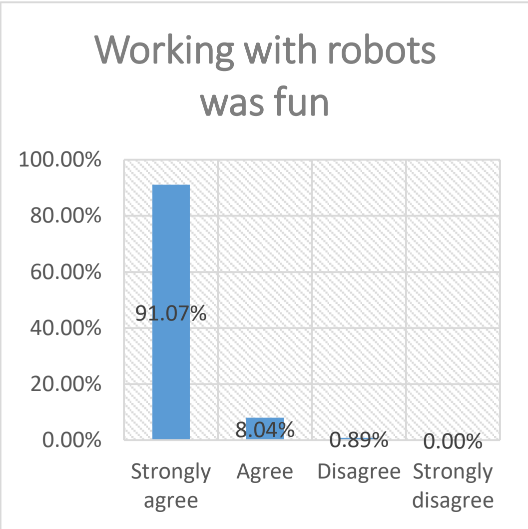


Figure 5. *Students' interest level during robotics classes*

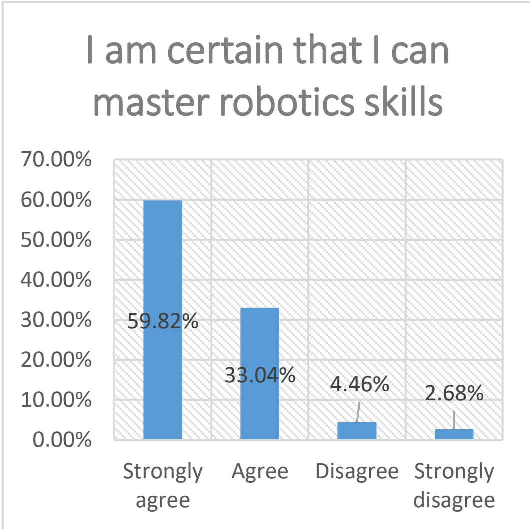


Figure 6. *Students' thoughts about mastering robotics skills*

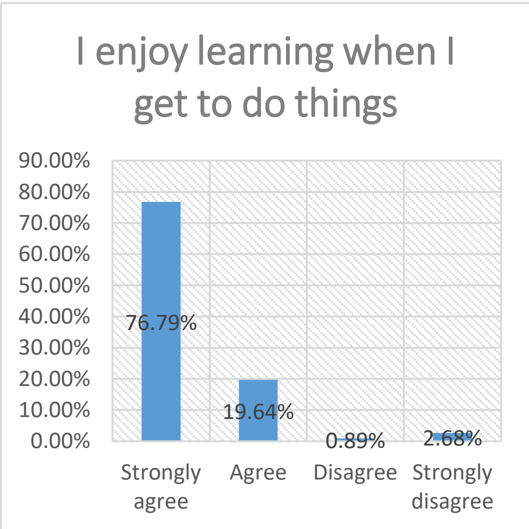


Figure 7. *Students' learning lifestyle*

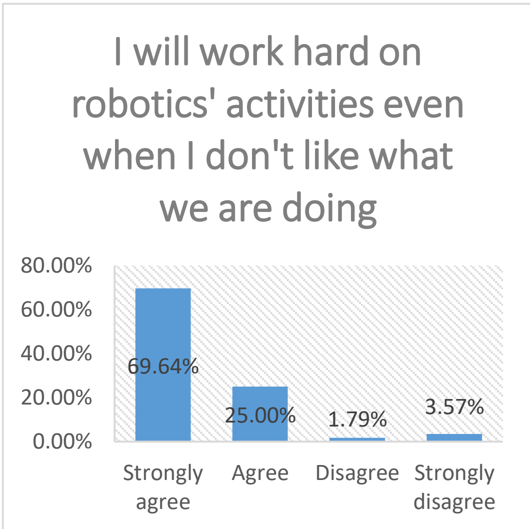
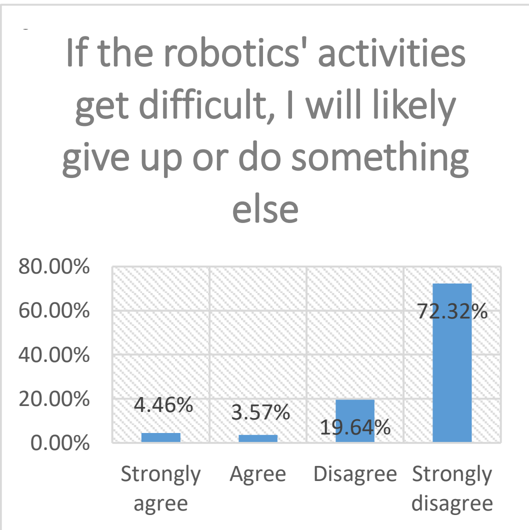


Figure 8. *Students' willing to work hard with robotics activities*



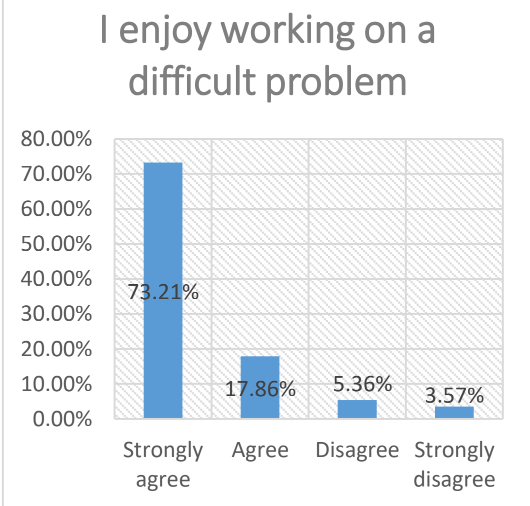
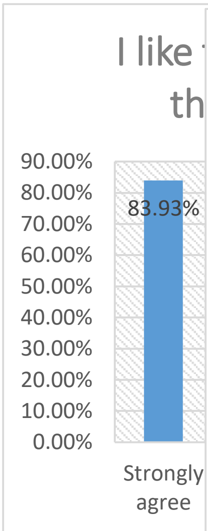


Figure 9. *Students' willing to complete difficult robotics activities*

Figure 10. *Students' willing to work on difficult problems*



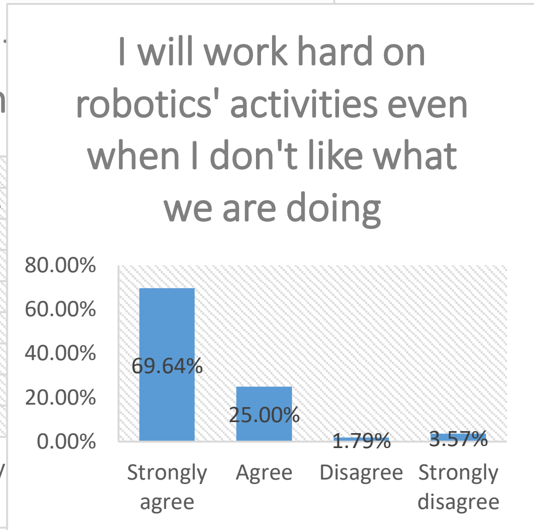
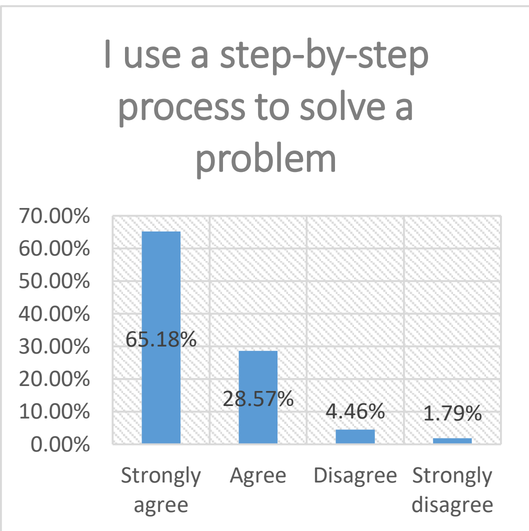


Figure 11. *Students' desire to know how things are working*

Figure 12. *Students' desire to work with robotics activities even if they don't like what they are doing*



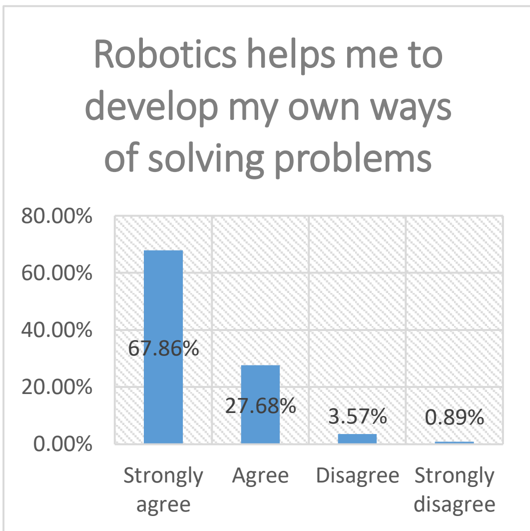


Figure 13. *Students' strategies in solving problems*

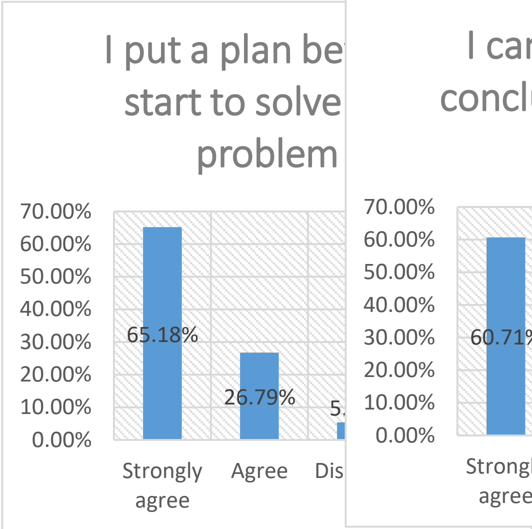


Figure 14. *Robotics' effect on students' problem-solving skills*

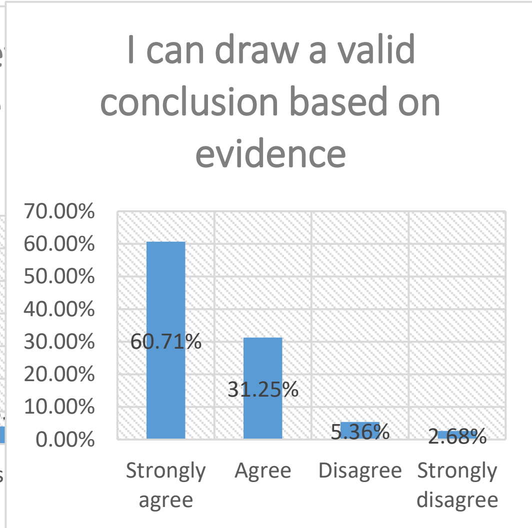


Figure 15. *Students' problem solving' skills*

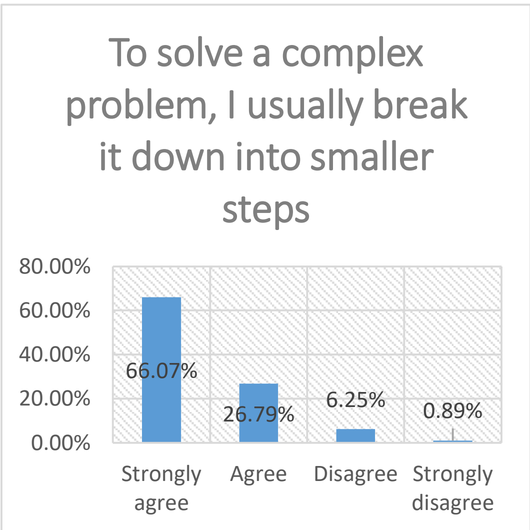


Figure 16. *Students' ability to conclude a valid conclusion*

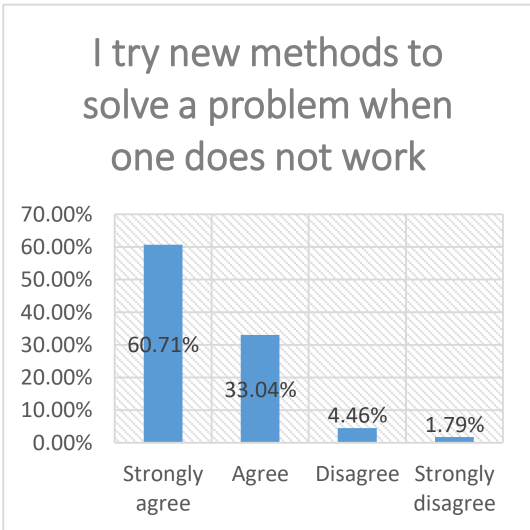


Figure 17. *Students' strategies to solve complex problems*

Figure 18. *Students' strategies to solve challenging problems*

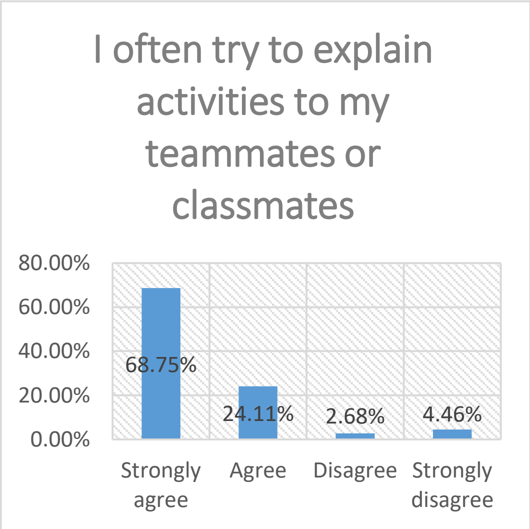


Figure 19. *Students' willing to explain the activities to their teammates*

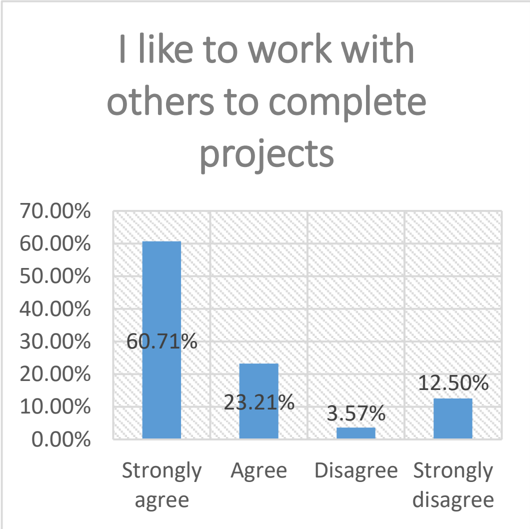


Figure 20. *Students' preference to work in groups*

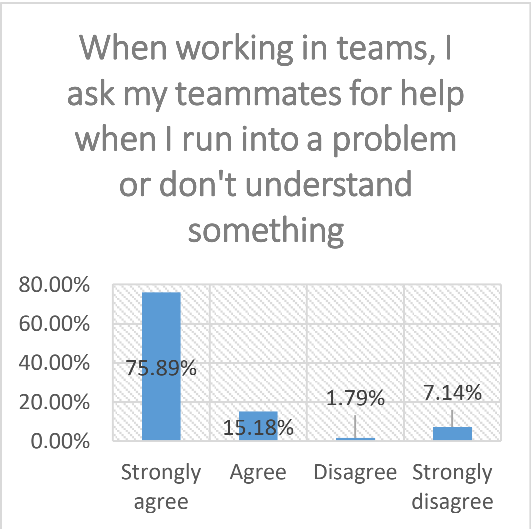


Figure 21. *Students' teamwork skills*

Appendix 3:

Students' assessments results

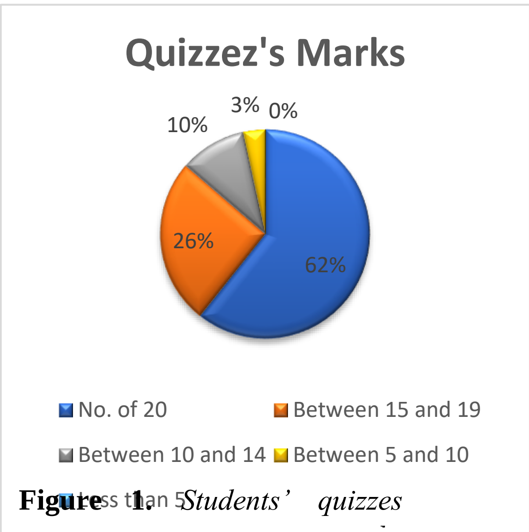


Figure 1. *Students' quizzes*

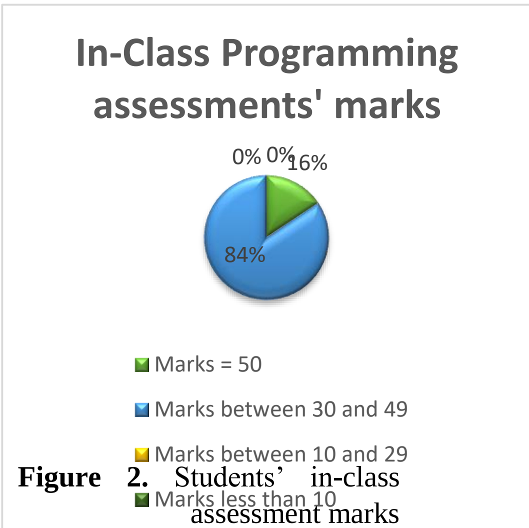


Figure 2. Students' in-class assessment marks

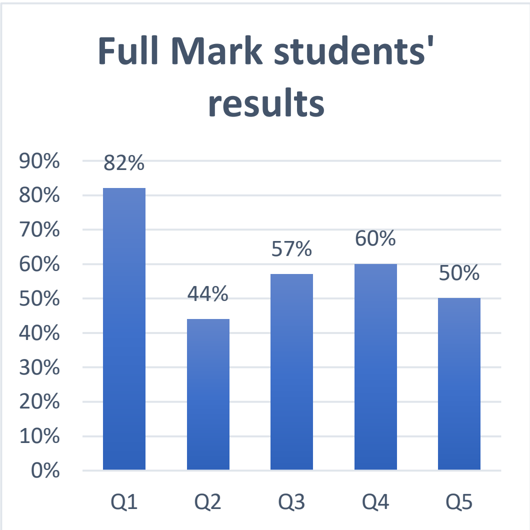


Figure 3. *Full Mark students' results in in-class assessment*

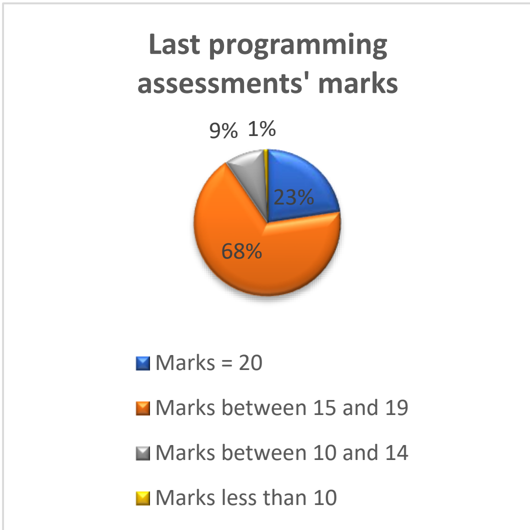


Figure 3. *Students' last programming assessment marks*