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UCTS FOUNDATION STUDENTS' PERCEPTION TOWARDS ARDUINO AS A TEACHING AND LEARNING TOOL IN STEM EDUCATION

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ABSTRACT

This paper presents the perception of University College of Technology Sarawak (UCTS) students on the implementation of the Arduino lessons incorporated in Foundation in Science (FIS) and Foundation in Arts (FIA) programmes as part of STEM education. The low number of students studying or applying for STEM fields has been alarming in regards to the nation's future workforce needs. Efforts have been made to attract more students to STEM programmes and careers. This study is intended to examine whether Arduino, as a teaching and learning tool, helps in generating students' interests towards STEM programmes. Arduino is one of the physical computing tools which has open-source electronics platform based on user-friendly hardware and software for creating different projects and applications. Arduino is easy to be used by beginners, yet flexible enough for advanced users to learn physical computing and programming. Results revealed that participating students felt that they learnt programming the most during Arduino learning process and Arduino is proven to cultivate their STEM interests and 21st century skills. In this paper, the students' awareness and experiences on learning Arduino in STEM education were studied. This study can be used to determine whether educational institutions should implement Arduino lessons to promote STEM interests among the students which further lead them to opt for STEM-related degree programmes and careers.

Keywords: Arduino, STEM education, STEM interest, 21st century skills, STEM programmes

INTRODUCTION

STEM education is defined as pedagogical application-based design and engineering technology for teaching content and practice in Science and Mathematics using educational technology. STEM education includes approaches that explore teaching and learning between two or more areas of STEM subjects (Sanders 2009). Malaysia is pursuing STEM education in order to be prepared to achieve a developed nation that is able to face the challenges and demands of STEM-driven economy by 2020 (Ministry of Education 2013). The number of students who have chosen STEM fields has continued to decline in recent years (Halim & Subahan 2016). Currently, only 42% of middle school students in Malaysia chose to do Science, including technical and vocational programmes at high schools (MOE 2016). According to Vijaindren (2018), National Council for Scientific Research and Development reveals that Malaysia needs to have 500,000 scientists and engineers by 2020 to deal with the challenges of Industrial Revolution 4.0 (IR4.0). Therefore, it is paramount that our nation has more programmes and platforms to build interest in technology and engineering.

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REVIEW OF LITERATURE

There are in the literature a number of Arduino-based educational kits for academic research and educational robotics projects. Therefore, in the following paragraphs, we discuss a few examples of what is currently available to provide a general overview of the topic of research.

Hoffer (2012) teaches STEM education using Arduino in C Programming. To satisfy this need, a series of hands-on laboratory assignments that contain various electronic components and sensors are created and supervised by two educational trainers. This project provides an interdisciplinary, hands-on approach to teach C programming. Together, the trainers and lab assignments also introduce key concepts in math and science while allowing students hands-on experience with various electronic components and sensors. This will allow students to mimic real world applications of using the C programming language while exposing them to technology not currently introduced in many high school classrooms. The developed project is targeted at high school students performing at or above the junior level and uses the Arduino Mega open-source Microprocessor and software as the primary control unit.

Meanwhile, Mellodge and Russell (2013) uses the Arduino platform to enhance students' learning experiences. They present preliminary experiences using the Arduino microprocessor platform in the undergraduate computing curricula, at both the upper and lower levels. The goal is to enhance students' learning by engaging them in a contextualized project-based learning experience and introducing them to fundamental computing and engineering concepts in the context of a highly visual and easy to use environment.

Junior, Neto and Hernandez (2013) presents a low cost educational robotics kit based on the Arduino Uno platform. The prototype is intended to be applied in secondary (high) schools by means of educational workshops on robotics. The project is supported by a step-by-step documentation (e.g. booklet) that addresses basic physics, mathematics, logic programming and robotics concepts. It also offers all the steps for evolving in the construction of a robot, and it employs a block-structured environment (such as Minibloq) to allow easier programming.

Basalo (2014) utilises Arduino as a Learning Tool for a Mechanical Engineering Measurements Lab. She has found that students are not sufficiently engaged in laboratory courses. To solve this problem, she incorporates the Arduino platform as an additional teaching tool in the lab. Students will gain exposure to a wider variety of sensors and will understand the basics of data acquisition using Matlab. Innovation is being tested that semester for the first time in a mechanical engineering undergraduate laboratory. The low cost of the Arduino platform allows each student to borrow a board and a set of sensors for the entire semester. The feedback from the students is to have more open-ended and practical lab activities.

Arduino allows the students to experiment with new educational processes, experiences and ways of learning. Through problem based learning (PBL), students develop competencies necessary to be effective 21st century workforce, including problem solving, critical thinking, collaboration, communication, and creativity or innovation (Eguchi 2015). 21st century skills have been the focus of education reform in the developing countries. The Partnership for 21st Century Skills, an international organisation (http://www.p21.org/) that advocates for 21st century readiness for every student states that "In an economy driven by innovation and knowledge, society is facing complex business, political, scientific, technological, health and environmental challenges, collaborative relationship and social networking are crucial to competitiveness."

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Assessment & Teaching of 21st Century Skills, another organisation with international collaboration based in Australia (http://atc21s.org/), organizes 21st Century Skills into four broad categories as follows:

Table 1: 21st Century Skills

Categories	Descriptions
Ways of Thinking	Creativity, critical thinking, problem-solving, decision-making and learning
Ways of Working	Communication and collaboration
Tools for Working	Information and communications technology (ICT) and information literacy
Skills for Living in the World	Citizenship, life and career, and personal and social responsibility

Both organisations emphasise the importance of creativity, critical thinking, communication and collaboration (4Cs) as a key to success in the 21st century. 4Cs (Critical thinking, Communication, Collaboration and Creativity) are core skills for our students to be successful in the future (Eguchi 2013). In the following section, how Arduino helps promote 21st century skills among young students is explained.

RESEARCH METHODOLOGY

School of Computing and Creative Media of University College of Technology Sarawak (UCTS) believes that it is crucial for students to experience physical computing during their foundation year in the university. Throughout the computing curriculum, hands-on classes on Arduino as one of the teaching and learning tools for physical computing have been conducted. Problem based learning and project based learning (PBL) engage the students in hands-on activities to nurture an understanding and interest in STEM education. Science, Technology, Engineering and Mathematics (STEM) is a curriculum based on the idea of educating students in these four STEM disciplines in an interdisciplinary and applied approach based on real-world problems and applications. Technology will be the core knowledge regardless of any career choice as technology keeps evolving and we are surrounded by technologies and information that are constantly being renewed (Junior, Neto & Hernandez 2013).

Two computing courses are offered by UCTS in the foundation academic year. For Foundation in Science (FIS), Computing is a two-credit hour course offered in Semester 3, whereas for Foundation in Arts (FIA), Introduction to Computer Systems and Applications is a three-credit hour course offered in Semester 2. The goal of these courses is to introduce the field of computing using simple projects, electronics and programming. Arduino has been introduced to the students as a physical computing learning tool. According to Arduino official website (2018), Arduino is an open-source electronics platform based on easy-to-use hardware and software. It is intended for anyone making interactive projects. Arduino may have a direct impact on students in the sense that it brings to classroom live experiences by working on hands-on projects to build a prototype that can solve a real life problem. It can also trigger students' creativity, critical thinking, collaboration and communication skills that are being emphasised in 21st century skills.

The participants were the students from Foundation in Science (FIS) and Foundation in Arts (FIA). 100 FIA students of 2017/2018 session participated in Arduino learning from 6th November 2017 to 8th December 2018. 58 FIS students of 2017/2018 session participated in Arduino learning from 1st March 2018 to 6th April 2018. The students were divided into 10 teams of 5 or 6 students respectively. Arduino Uno microcontroller board was selected as the physical

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computing learning tool because it is an open-source hardware board that is becoming increasingly common within the teaching community (Grasel, Vonnegut & Dodds 2010). Arduino can interact with its surroundings through different types of sensors, switches, lights and motors. Each group was given a set of Arduino Starter Kit. Due to the limitation of the Arduino sets, the students were required to take turns to use the Arduino sets at different schedules to carry out their Arduino assignment tasks.

During the first lecture on Arduino Uno, the students were being briefed on the general knowledge and information on Arduino and followed by tutorial videos developed by Arduino hobbyists on YouTube. Students were prompted to watch an Arduino project video with the title of "Blink My First LED" in YouTube channel. Subsequently, the students were asked to carry out hands-on activities to explore and discover the components given in Arduino Starter Kits by doing some simple Arduino projects for beginners. The students downloaded Arduino IDE software from Arduino website at no cost to write programmes using C or C++ programming language. In order to familiarize the students with Arduino environment, several reference webpages, getting started videos, as well as sample projects were supplied. The students were being introduced to the basic programming concepts and syntax, for example, sequence, selection, looping, function and variables. Students' learning process during the Arduino lessons was evaluated through the observation of students' in-class activities and responses in an online questionnaire in regards to their learning experiences and learning of 21st century skills.

Table 2: Learning Types

Learning Types	Descriptions
Learning by Imitating	The students imitate examples to learn about Arduino and how to use them.
Learning by Modifying	The students modify the attributes and functions of the systems and programmes based on the basic examples.
Learning by Creating	The students apply the examples they have imitated and modified so far to design and develop new prototypes and programmes.

Table 2 above shows the learning types and their descriptions that are carried out by the students (Jang, Lee & Kim 2015). To enhance their learning experiences on Arduino, the students are given an assignment, that is learning by creating, which requires them to apply design thinking processes to identify a real life problem and build a prototype to solve it. The students work as a team to empathize and define the problem, brainstorm and come up with creative solutions, fabricate a prototype and test the prototype system. The students are given 4 weeks to complete their prototypes. The students are also required to capture a 5-minute video on their discovery learning process about Arduino. The students present their videos and share their learning experiences of Arduino during the presentation at the end of the semester of the computing course.

An online questionnaire form was designed to collect the data to study students' awareness and experiences on learning Arduino in STEM education from this batch of UCTS FIS and FIA students. The online questionnaire was designed with the consideration of three main domains; cognitive, affective and psychomotor. The questionnaire was divided into two main sections; Profile Data and Perception towards Arduino. The first section which consists of 10 multiple choice questions collected the demographics data on the profile and background of the participants. The second section comprises of 30 questions about the perception towards Arduino based on Likert Scale from 1 to 5 (1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, or 5: Strongly

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Disagree). Reliability tests on the questionnaire were carried out prior to its distribution to the participants.

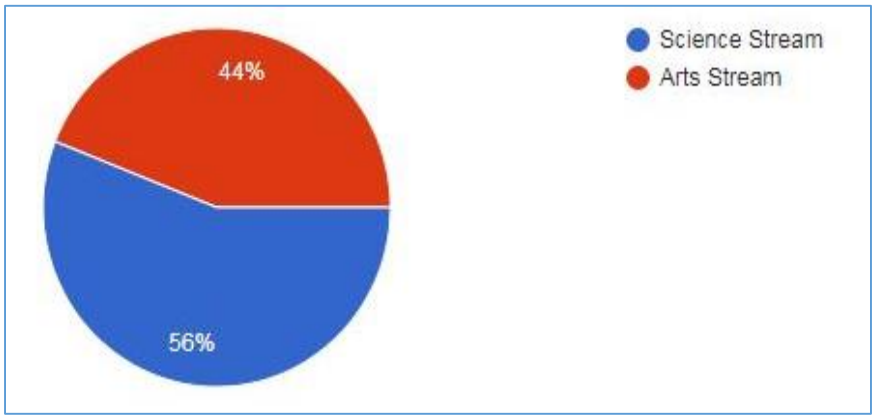
From 19th to 26th September 2018, an online questionnaire was distributed to the students who had participated in Arduino learning lessons under UCTS Foundation Programmes for the cohort of 2017/2018. An invitation was extended to the aforementioned students to fill the online questionnaire via Edmodo groups. 50 students responded and submitted the online questionnaire within a week of data collection. The participation in this online questionnaire was voluntary. All the data collected were kept anonymous and confidential.

RESEARCH FINDINGS

The data obtained from the questionnaire was analysed with descriptive statistics by using frequency in percentage form. The sample size, *n*, equals to 50. Among the 50 participants, 21 were male students (which was 42%) and 29 were female students (which was 58%). The majority of the questionnaire participants aged 19 years old, amounting to 68%. The majority of the questionnaire participants were from Sibu, which was 66%.

Among the questionnaire participants, 28 students (which was 56%) were from Science Stream in Sijil Pendidikan Malaysia (SPM) level, whereas 22 students (which was 44%) were from Arts Stream. (Refer to Figure 1)

Figure 1: SPM Science Stream versus SPM Arts Stream



Among these participants, 16 students studied Foundation in Science (which was 32%) and 34 students studied Foundation in Arts (which was 68%). (Refer to Figure 2)

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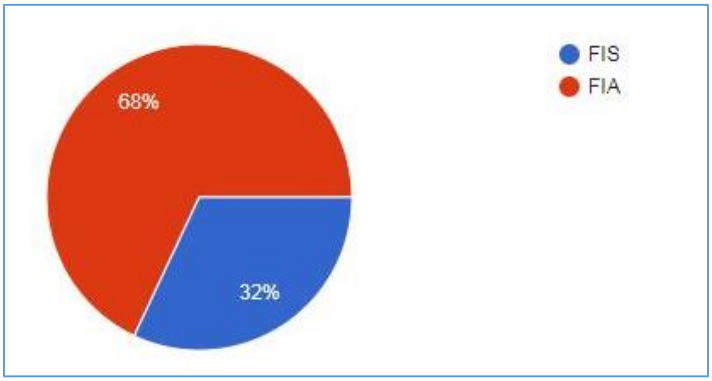
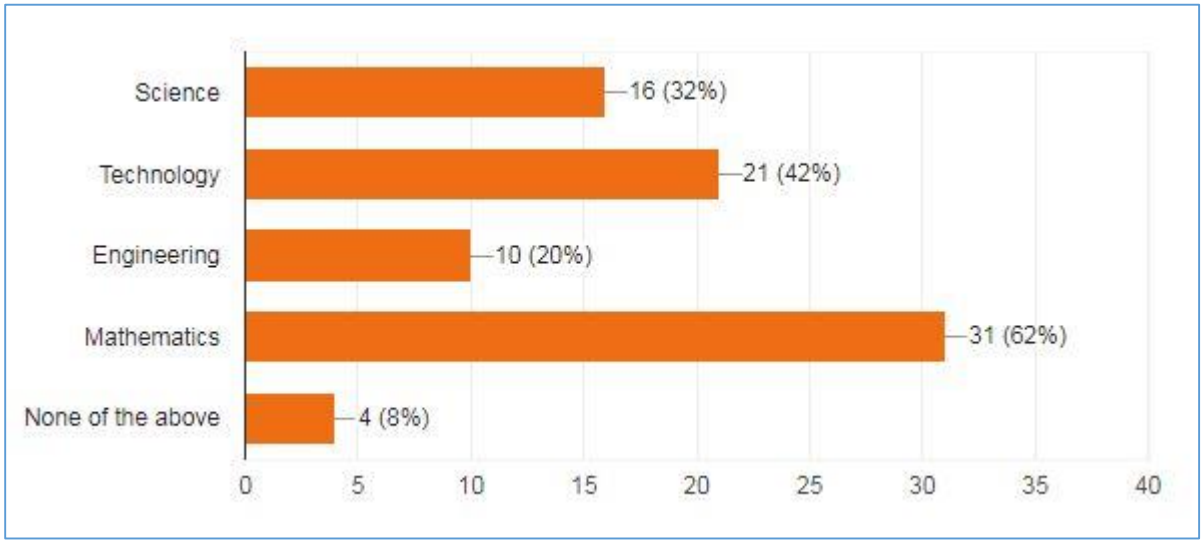
Figure 2: UCTS FIS versus UCTS FIA



The analysis of the data for the first section on multiple choice questions (based on 50 questionnaire respondents) indicated the following results:

Question 1: Which STEM subjects do you like the most?
Overall, 46 students (which was 92%) responded that they like STEM subjects (Science, 32%; Technology, 42%; Engineering, 20%, Math, 62%). (Refer to Figure 3)

Figure 3: Which STEM subjects do you like the most?



Question 2: Have you heard about Arduino before you taking FIA or FIS programme?
Only 13 students (which was 26%) students indicated that they have heard about the name of Arduino before joining FIS or FIA. This shows that the majority of the participating students got to know Arduino in the university instead of at secondary or high schools. (Refer to Figure 4)

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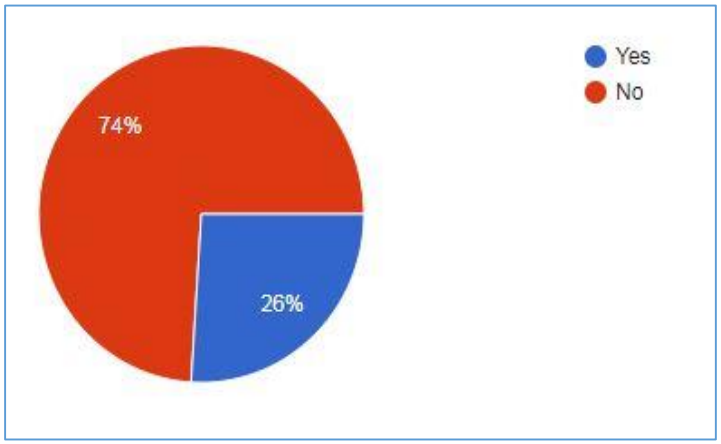
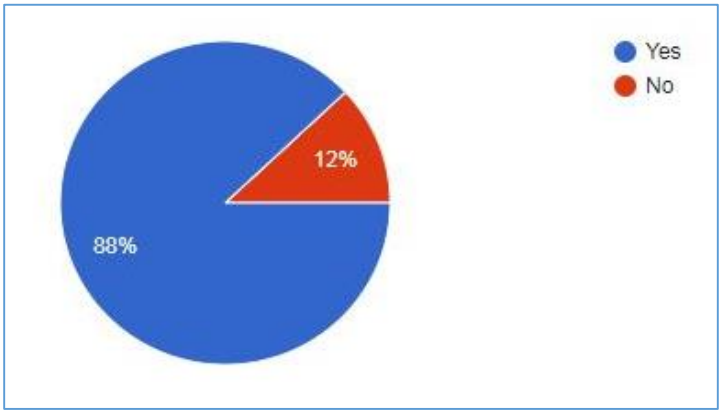
Figure 4: Have you heard about Arduino before you taking FIA or FIS programme?



Question 3: Does Arduino help you to enjoy learning STEM subjects more?
The majority of students, 44 students out of 50 students (which was 88%) agreed that Arduino did help them to enjoy learning STEM subjects. (Refer to Figure 5)

Figure 5: Does Arduino help you to enjoy learning STEM subjects?



Question 4: What did you learn the most from Arduino learning process?
The results show that 18 students agreed that they learned programming the most (which was 36%). The ranking is followed by teamwork or collaboration as well as creativity and critical thinking with 24% respectively. Then, electronics is at 12% and lastly communication skills, 2%. (Refer to Figure 6)

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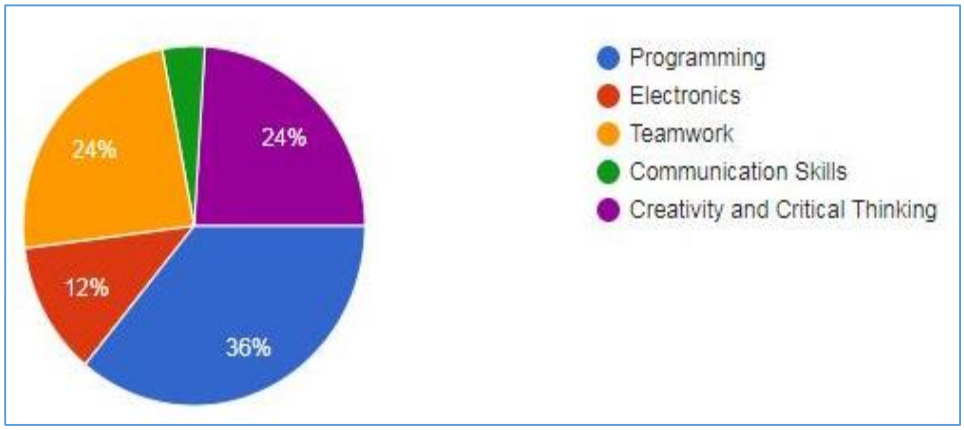
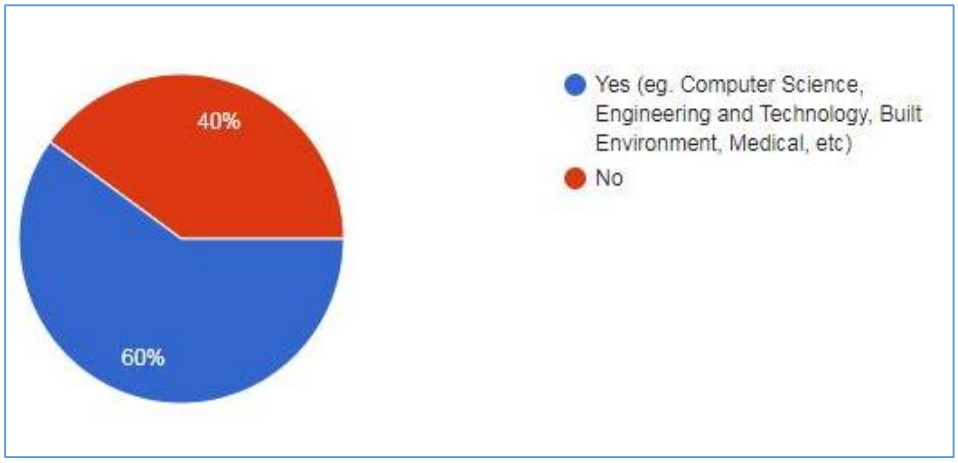
Figure 6: Does Arduino help you to enjoy learning STEM subjects?



Question 5: Do you consider choosing STEM-related degree?
60% of the students agreed that they were interested in choosing STEM-related degree. (Refer to Figure 7)

Figure 7: Do you consider choosing STEM-related degree?



The analysis of the data for the second section on 30 questions of 5-point Likert scale (1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, or 5: Strongly Disagree) about the students' perception towards Arduino indicated the following results:

Question 1: Basic knowledge about Arduino
The participants were asked whether they know the basic functions of Arduino and how to connect Arduino. The results show that a total of 26% of students agreed and strongly agreed that they have basic knowledge about Arduino. (Refer to Figure 8)

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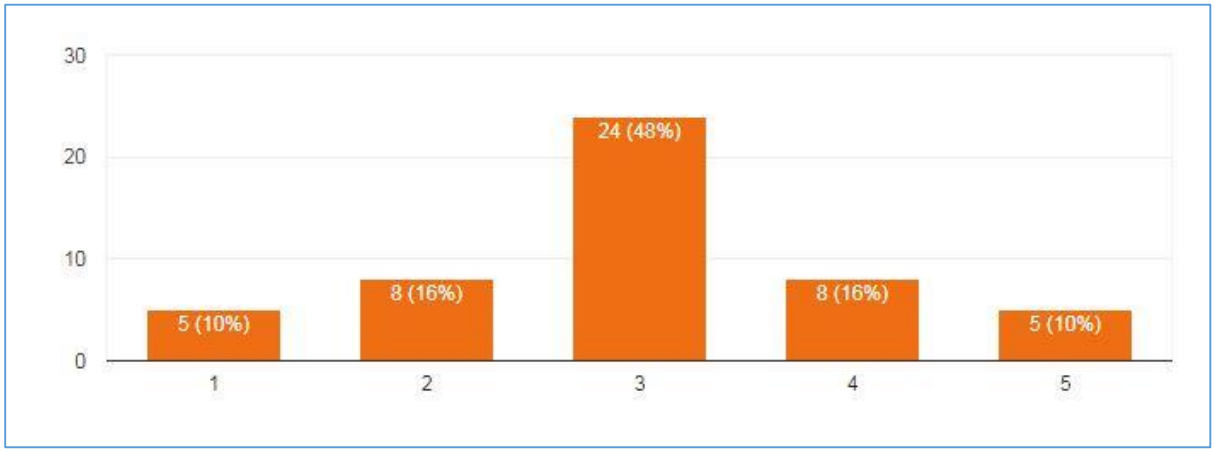
Figure 8: I have basic knowledge about Arduino.



Question 2, 3 and 4: Sources of Learning Arduino

Question 2 asked the participating students whether they learned Arduino from teachers. Based on the data analysis, the results show that 6% of students (that was 3 students) strongly agreed that they learned Arduino from their secondary teachers. Question 3 asked participating students whether they learned Arduino from websites and YouTube videos. The results show that a total of 46% of students agreed and strongly agreed that they learned Arduino from YouTube videos (Refer to Figure 9). Question 4 asked whether the students play to explore and learn Arduino. The results show that 64% of students (that was 32 students) agreed and strongly agreed that they learned Arduino through play and exploration (Refer to Figure 10).

Figure 9: I learned Arduino from websites and YouTube videos.

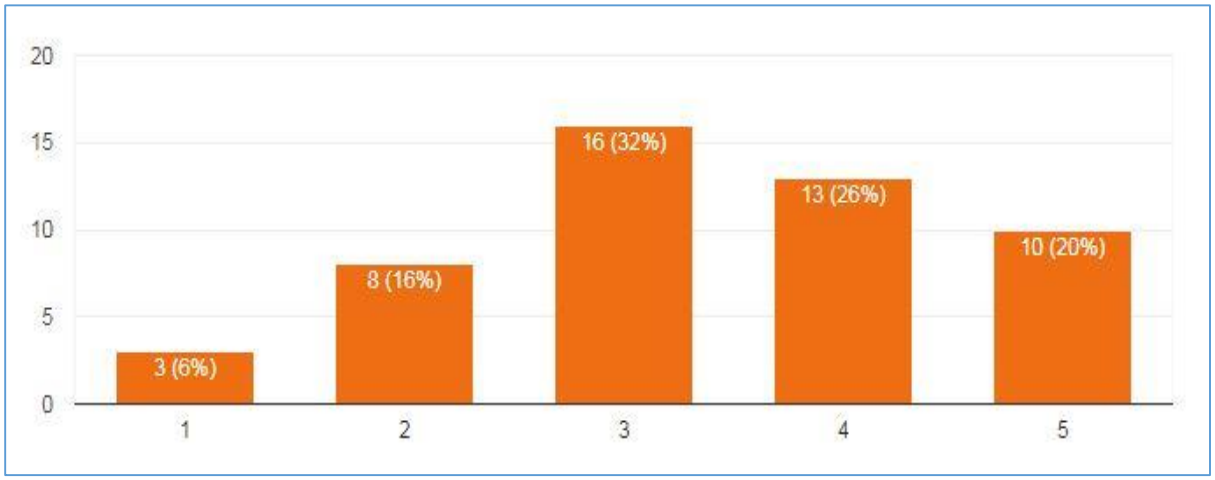


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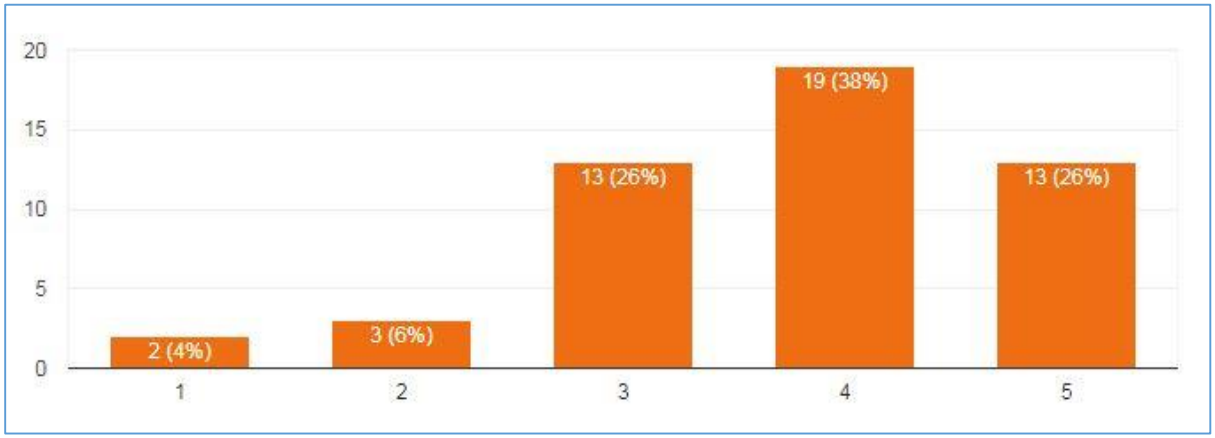
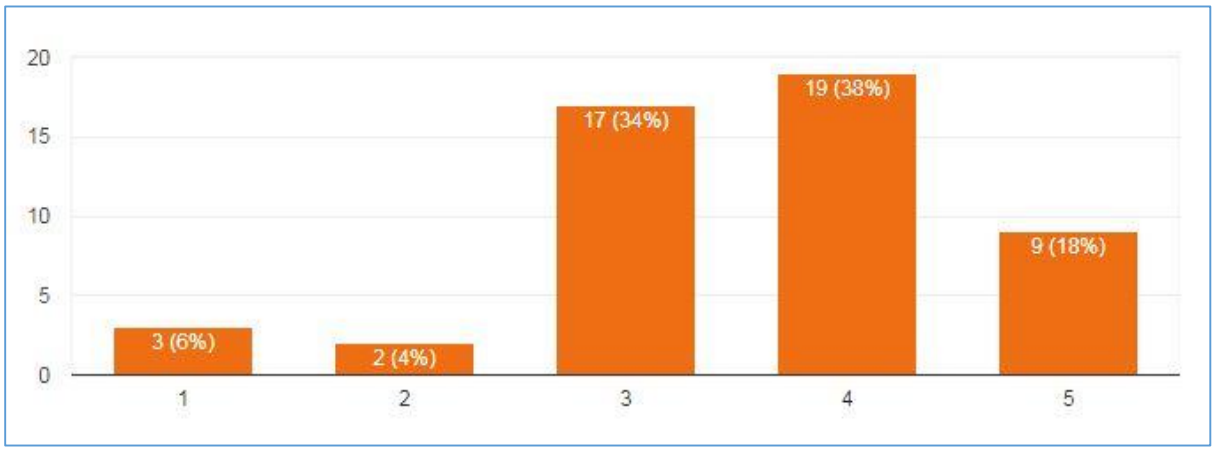
Figure 10: I play with Arduino and I learn.



Question 5: Knowledge and skills to use Arduino to make something
When the participating students were asked whether they know how to make something, i.e. prototype from Arduino, the results show that 22% of students (that was 11 students) agreed and 16% of students (that was 8 students) strongly agreed that they know how to make something from Arduino.

Question 6: Like Arduino projects or assignments
This question asked the participating students whether they like to use Arduino to do projects or assignments. The results show that 56% of students (that was 28 students) responded that they like and strongly like to do Arduino projects or assignments. (Refer to Figure 11)

Figure 11: I like doing Arduino projects or assignments.



Question 7 and 8: Give life to own ideas through Arduino
Question 7 asked whether the participating students explore new ideas and discover new things using Arduino via trials and experiments. The results show that a total of 54% of students (that

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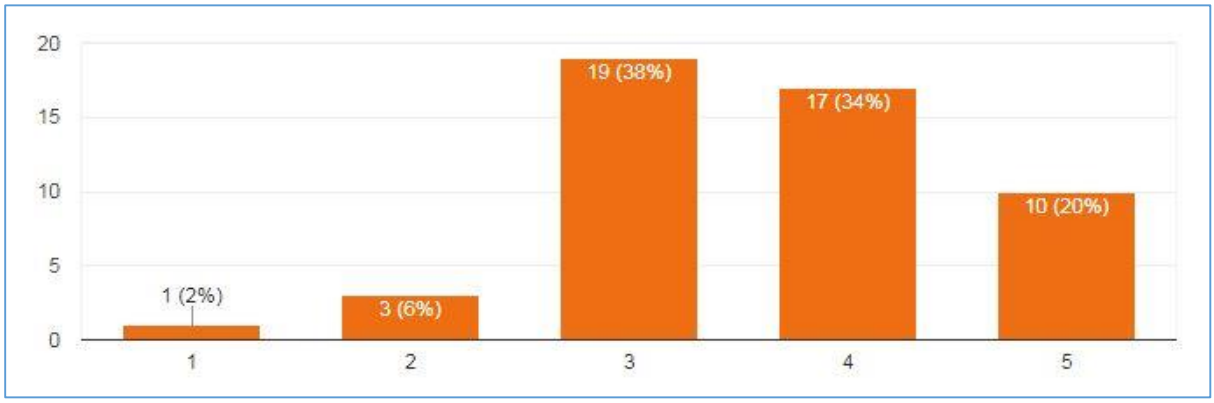
was 27 students) agreed and strongly agreed that they explore new ideas and discover new things using Arduino (Refer to Figure 12). Question 8 asked whether the participating students use Arduino to transform their ideas into reality. The results show that a total of 40% of students (that was 20 students) agreed and strongly agreed that they transform their ideas into reality to make it happen.

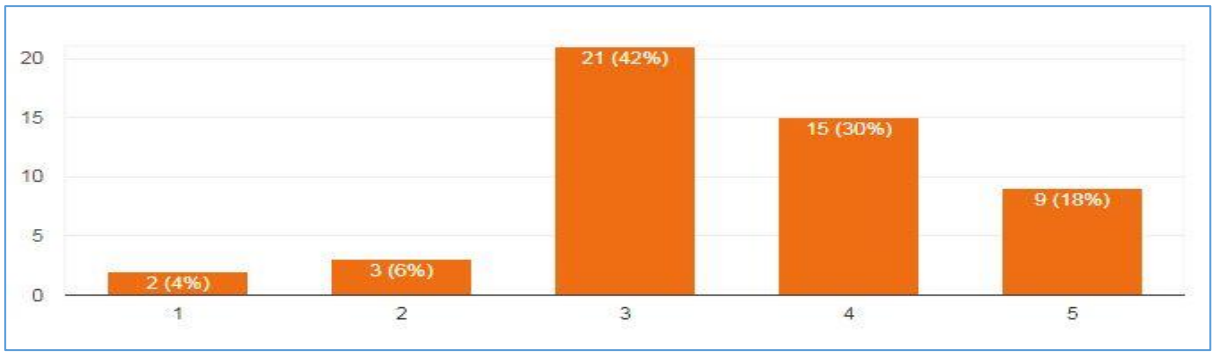
Figure 12: I explore new ideas and discover new things using Arduino.



Question 9: Critical thinking skills

When the participants were enquired whether learning Arduino improves critical thinking skills through problem solving skills, the results show that a total of 48% of students (that was 24 students) agreed and strongly agreed that learning Arduino improves critical thinking skills which involves problem solving. (Refer to Figure 13)

Figure 13: Learning Arduino improves my critical thinking skills through problem solving.



Question 10: Creativity and innovation

This question asked whether learning Arduino cultivates the students to think creatively and imaginatively. The results show that a total of 54% of students (that was 27 students) agreed and strongly agreed that Arduino learning process helps them think creatively and imaginatively. (Refer to Figure 14)

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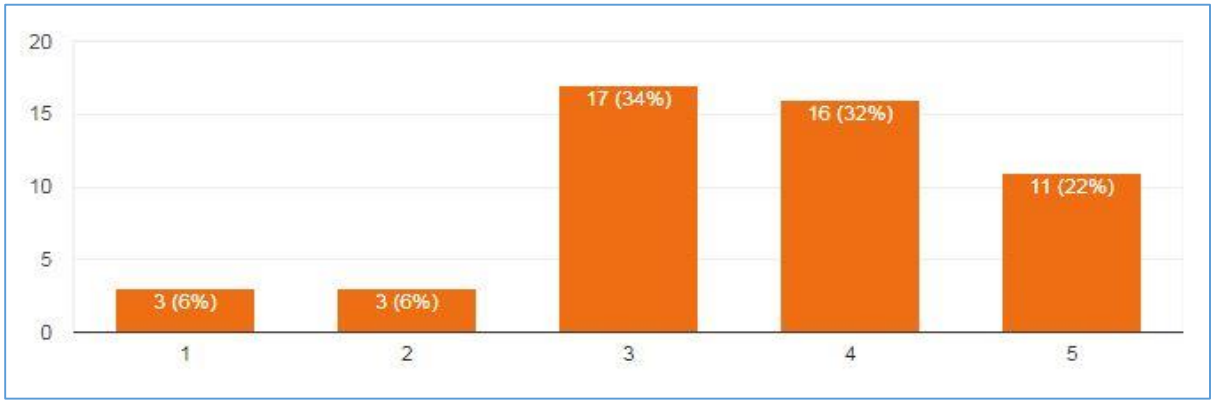
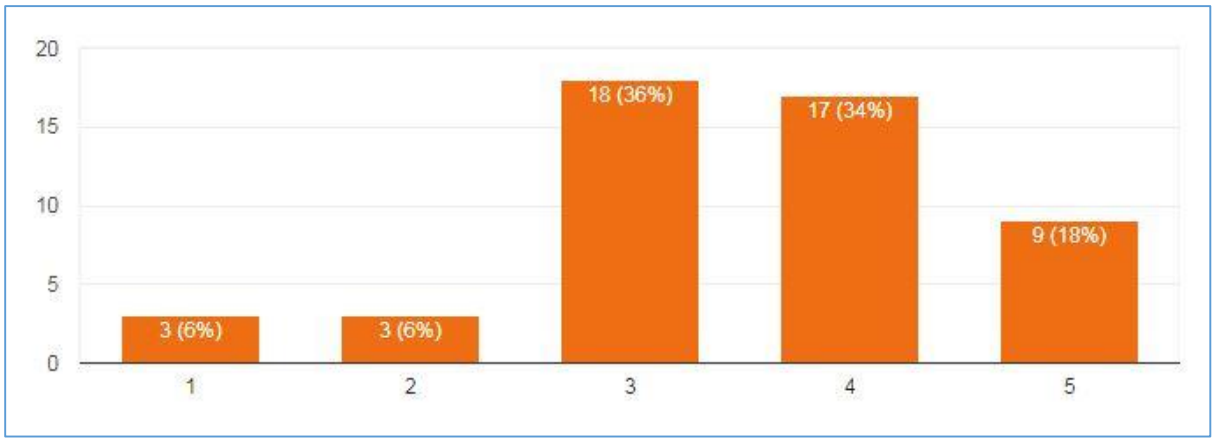
Figure 14: Learning by doing through Arduino requires me to think creatively and imaginatively.



Question 11 and 12: Communication skills

Question 11 asked whether doing Arduino projects in group enables the students to communicate their ideas among team members. The results show that 38% of students (that was 12 students) agreed and 12% of students (that was 6 students) strongly agreed that Arduino learning process helps them to talk about their ideas to others. Question 12 asked whether communicating Arduino project's ideas in a group improves students' communication skills. The results show that a total of 52% of students (that was 26 students) agreed and strongly agreed that they improve communication skills indirectly when they express and convey the ideas or messages among the team members. (Refer to Figure 15)

Figure 15: Talking about my ideas while doing Arduino projects in a group improves my communication skills.



Question 13: Teamwork and collaboration

When the participants were asked whether doing Arduino projects in a group encourages students' collaboration, the results show that a total of 60% of students (that was 30 students) agreed and strongly agreed that by doing Arduino group project, they collaborate with others in a team. (Refer to Figure 16)

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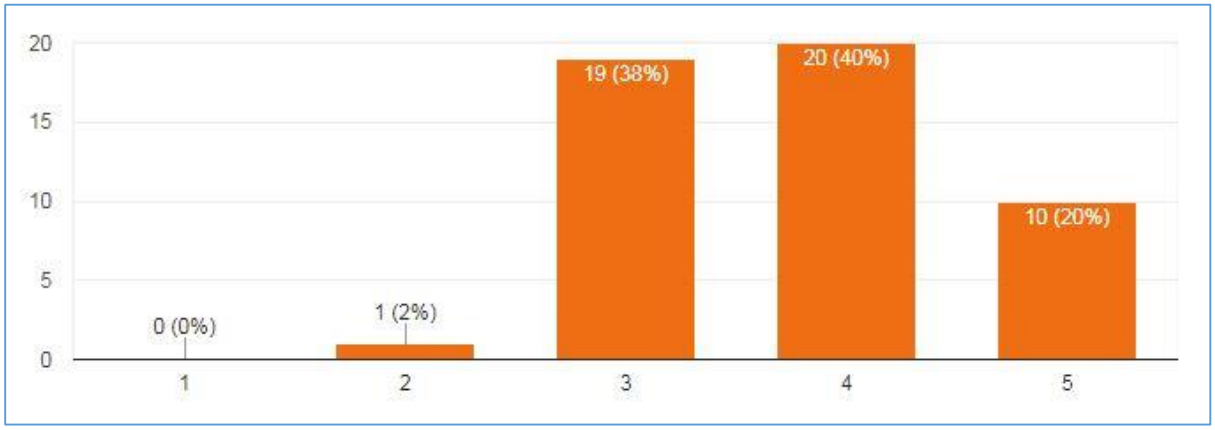
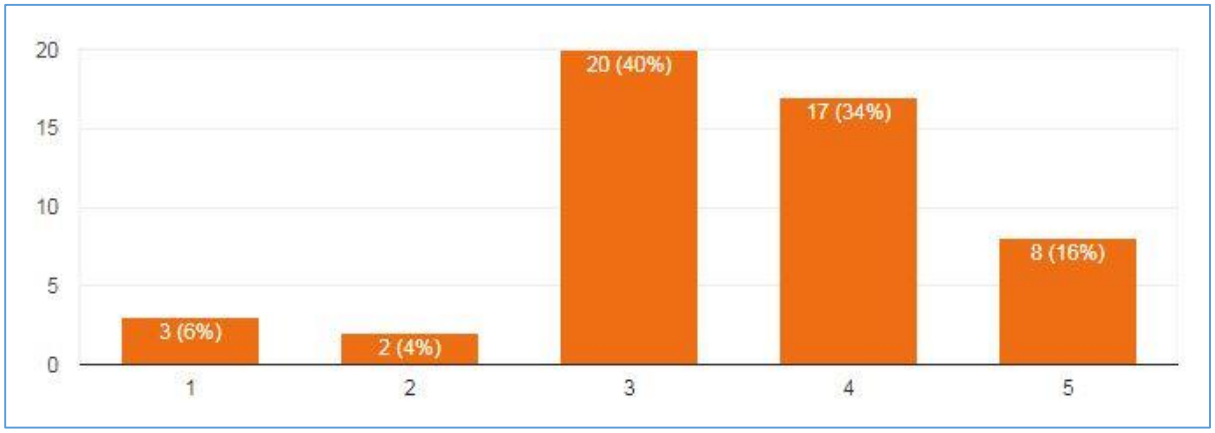
Figure 16: Doing Arduino projects in a group encourages me to collaborate with others.



Question 14 and 15: Fun and engaging factor

Question 14 asked whether the students are interested to learn Arduino because it is fun and engaging. The results show that 50% of students (that was 25 students) agreed that they are interested to learn Arduino because it is fun and engaging as it can attract their interests of learning (Refer to Figure 17). Question 15 asked whether the students are interested to do Arduino projects because they treat it as a hobby. The results show that 20% of students (that was 10 students) agreed and 8% of students (that was 4 students) strongly agreed that they are the hobbyists of Arduino to make something workable and impactful.

Figure 17: I am interested to learn Arduino as it is fun and engaging.



Question 16, 17, 19 and 23: Usefulness and impact

Question 16 asked whether the students are interested to do Arduino projects because it utilizes their time wisely. The results show that 38% of students (that was 19 students) agreed and 6% of students (that was 3 students) strongly agreed that by doing Arduino projects, they spent their time wisely. Question 17 asked whether the students feel it would be beneficial to do Arduino projects or assignments. The results show that a total of 60% of students (that was 30 students) agreed and

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strongly agreed that it is beneficial by doing Arduino projects (refer to Figure 18). Question 19 asked whether Arduino is a great teaching and learning tool to understand basic electronics and programming. The results show that a total of 60% of students (that was 30 students) agreed and strongly agreed that Arduino is a great teaching and learning tool to understand basic electronics and programming (refer to Figure 19). Question 23 asked whether doing Arduino projects gives students the chance to learn a wide range of topics including electronics, electro mechanics, computing, sensors, programming and logic. The results show that a total of 54% of students (that was 27 students) agreed and strongly agreed that Arduino gives students the chance to learn a wide range of topics (refer to Figure 20).

Figure 18: I think it would be beneficial to me to do Arduino assignments.

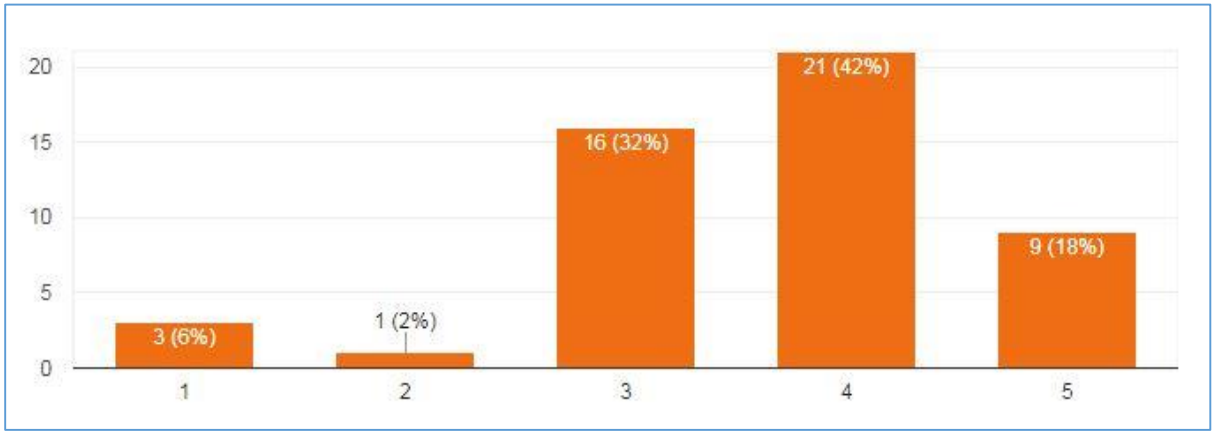

Figure 19: I enjoy learning Arduino as it is a great teaching and learning tool to understand basic electronics and programming.

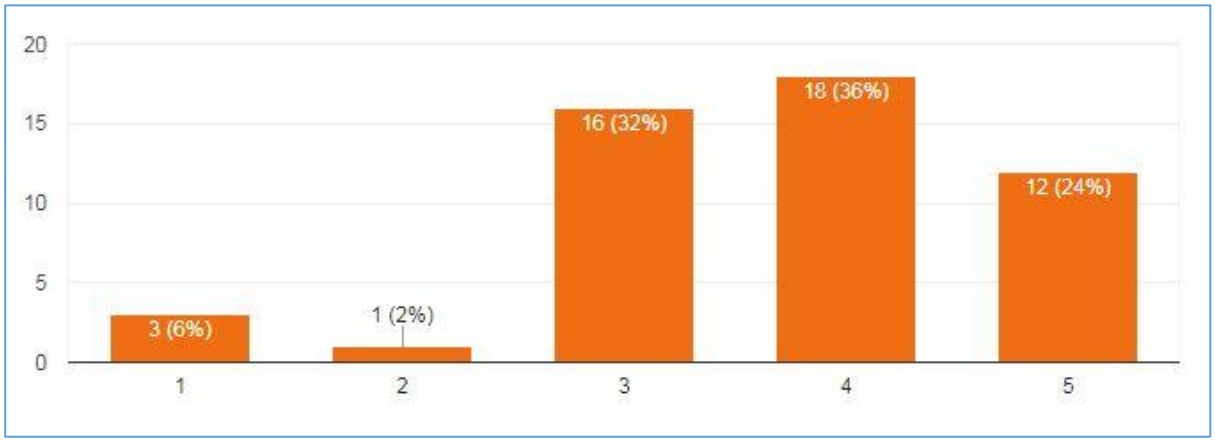

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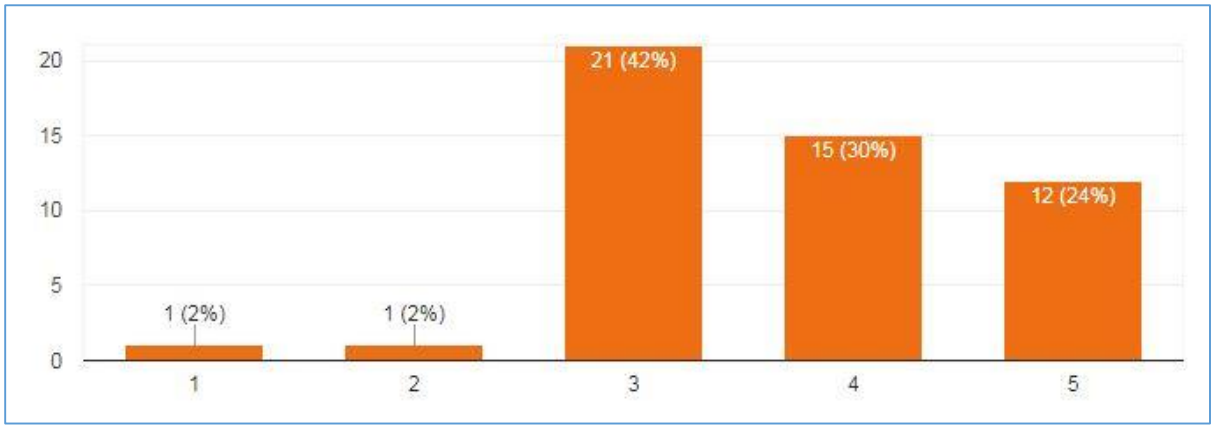
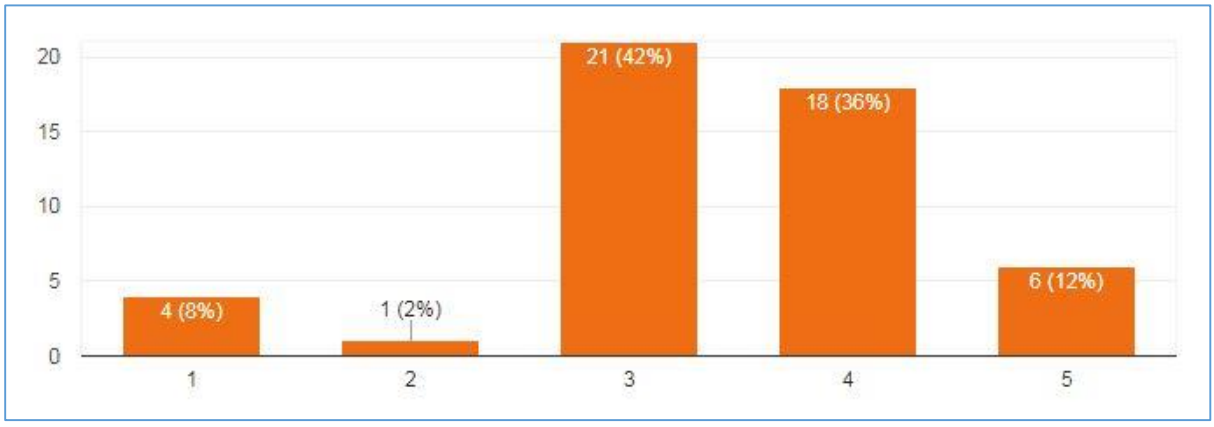
Figure 20: Doing Arduino projects gives me the chance to learn a wide range of topics including electronics, electro mechanics, computing, sensors, programming and logic



Question 18: Curiosity

The students were asked if they are interested to do Arduino projects because it can pique their curiosity. The results show that a total of 48% of students (that was 24 students) agreed and strongly agreed that by doing Arduino projects, it piques their curiosity. (Refer to Figure 21)

Figure 21: I am interested to do Arduino projects because it can pique my curiosity.



Question 20, 21 and 22: Character development

Question 20 asked whether the success in making Arduino projects gives students a sense of achievement and boosts their self-esteem. The results show that a total of 54% of students (that was 27 students) agreed and strongly agreed that completion of Arduino projects boosts their self-esteem (refer to Figure 22). Question 21 asked whether Arduino projects improve self-motivation and confidence. The results show that 30% of students (that was 15 students) agreed and 20% of students (that was 10 students) strongly agreed that completion of Arduino projects improve self-motivation and confidence. Question 22 asked whether Arduino projects cultivate determination in getting things done and train students to be patient. The results show that 32% of students (that was 16 students) agreed and 20% of students (that was 10 students) strongly agreed that completion of Arduino projects cultivate determination and patience.

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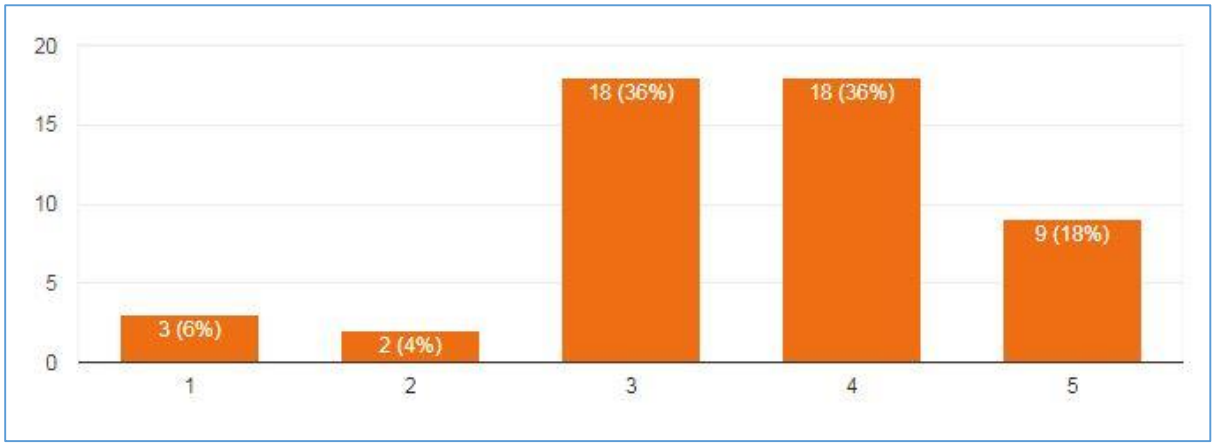
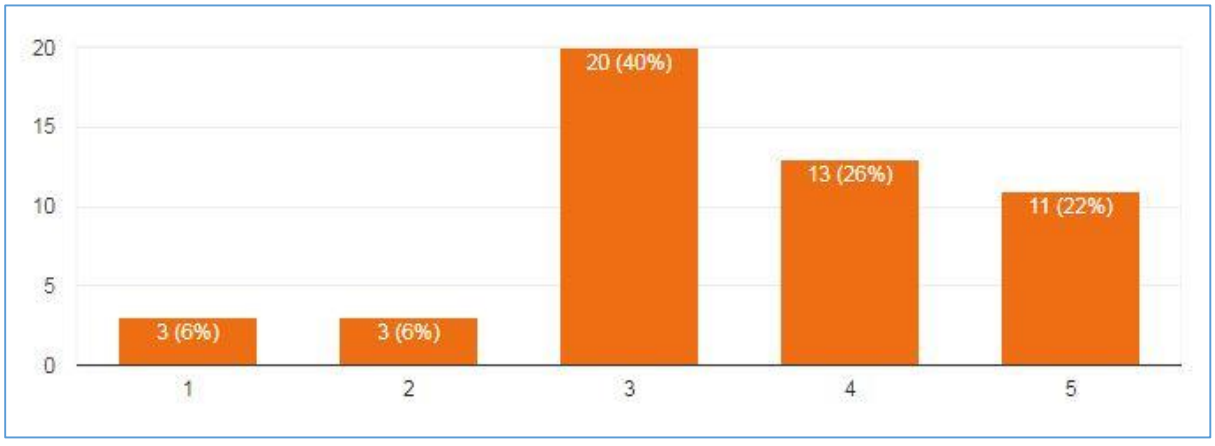
Figure 22: I believe success in making Arduino projects gives me a sense of achievement and boosts my self-esteem.



Question 24 and 25: Availability and accessibility of Arduino kit
Question 24 asked whether the students mind to buy a set of Arduino to do Arduino projects at home. The results show that 24% of students (that was 12 students) agreed and 10% of students (that was 5 students) strongly agreed that they do not mind to buy a set of Arduino to do Arduino projects at home. Question 25 asked whether if a free set of Arduino has been given, the students will try to do Arduino projects at home. The results show that 48% of students (that was 24 students) said they are willing to do Arduino projects at home if Arduino kit is given freely (refer to Figure 23).

Figure 23: If I am given a free set of Arduino, I will try to do Arduino projects at home.



Question 26, 27 and 28: Arduino innovation competitions
Question 26 asked whether the students are willing to enter innovation competitions by using Arduino to create a prototype. The results show that 26% of students (that was 13 students) agreed and 16% of students (that was 8 students) strongly agreed to show their willingness to enter Arduino competitions. Question 27 asked whether students would like to make a difference by creating something of value to the society that will solve real problems. The results show that 26%

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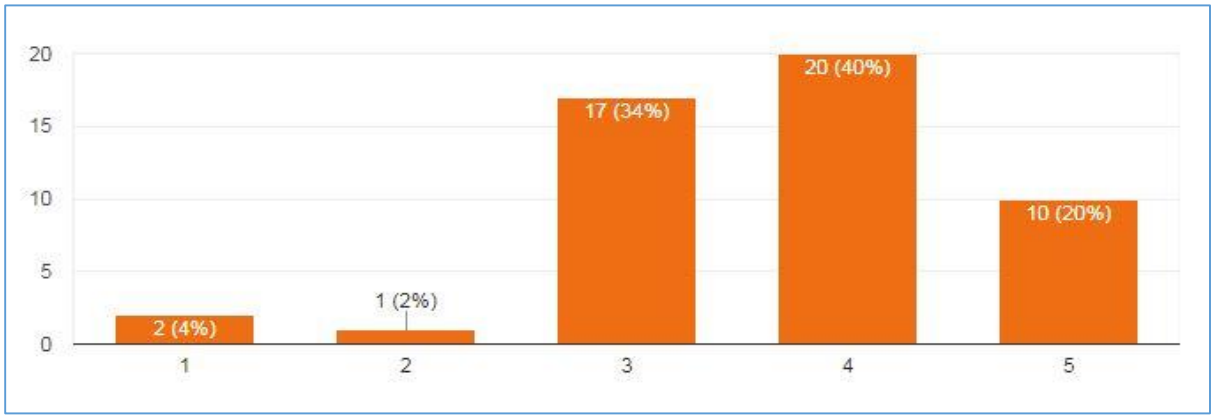
of students (that was 13 students) agreed and 16% of students (that was 8 students) strongly agreed to create something of value to the society that will solve real problems. Question 28 asked whether the students feel satisfied if their Arduino prototype idea gives impact to society. The results show that a total of 60% of students (that was 30 students) feel satisfied and strongly satisfied if their Arduino prototype idea gives impact to society (refer to Figure 24).

Figure 24: I feel satisfied if my Arduino prototype idea gives impact to society.



Question 29 and 30: STEM programmes or STEM-related degrees

Question 29 asked whether learning Arduino motivates students to continue their studies in STEM programmes, such as Computer Science, Electronic Engineering, Mechanical Engineering or technology related programmes. The results show that a total of 38% of students (that was 19 students) were motivated and strongly motivated to continue their studies in STEM programmes due to Arduino lessons (refer to Figure 25). Question 30 asked whether learning Arduino helps students to make a better decision in pursuing a degree related to Science, Technology, Engineering and Mathematics (STEM). The results show that a total of 44% of students (that was 22 students) agreed and strongly agreed that learning Arduino helps them to make a better decision in pursuing a STEM-related degree (refer to Figure 26).

Figure 25: Learning Arduino motivates me to continue my studies in STEM programmes, such as Computer Science, Electronic Engineering, Mechanical Engineering or technology related programmes.

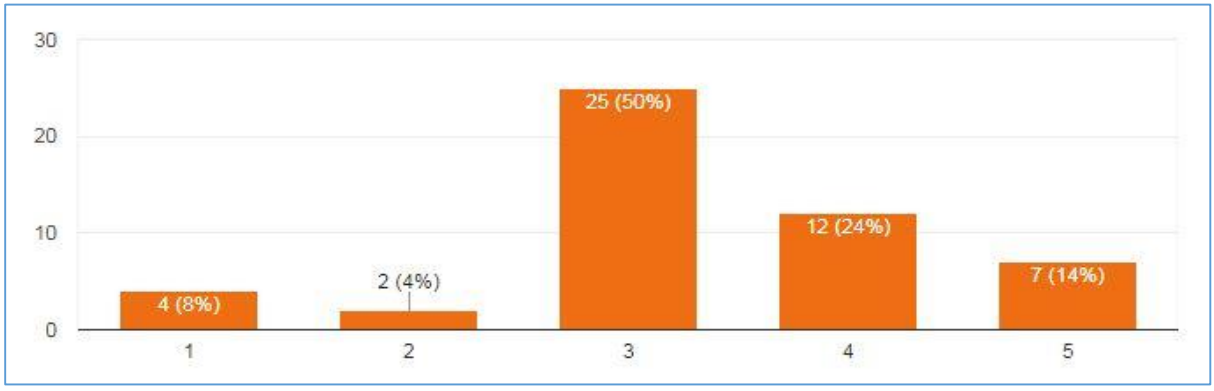


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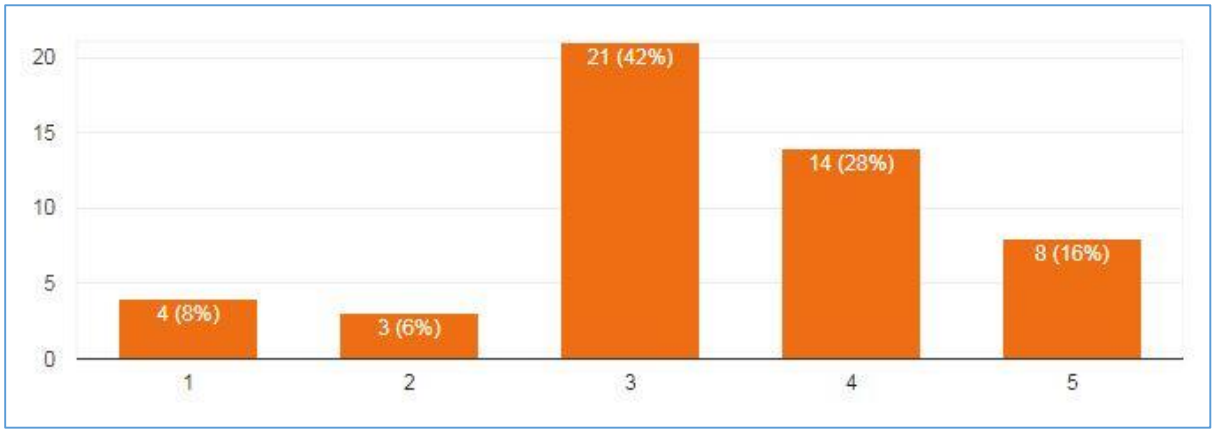
Figure 26: Learning Arduino helps me to make a better decision in pursuing a degree related to Science, Technology, Engineering and Mathematics (STEM).



DISCUSSIONS

Although 92% of students (refer to Figure 3) were already interested in STEM areas, some students still opt to study FIA instead of FIS. 56% of the students were SPM Science Stream students (refer to Figure 1) but the enrolment in Foundation in Science is only at 32% (refer to Figure 2). Based on the empirical experience, the students were not confident or had reservations to further their studies in Science stream. 74% of the students revealed that they were not aware of Arduino until they were introduced to Arduino in the university level (refer to Figure 4). 88% of the students agreed that Arduino plays a significant role in enabling them to enjoy to learn STEM subjects. This shows that their experiences participating in Arduino have positive impact on their interests in the STEM fields.

Overall, the above results indicate that the students who participated in this online questionnaire like STEM subjects, especially Mathematics (refer to Figure 3). It was proven that Arduino makes the students enjoy learning STEM subjects (refer to Figure 5). Since Arduino in general attracts students who are interested in STEM, the result of choosing STEM-related degree is not surprising (refer to Figure 7). Moreover, the results from the third question indicate that their participation in Arduino increased their decision to consider to enrol in a STEM degree (refer to Figure 5). This is notable when we analyse Figure 2 where out of 32% of enrolled FIS students who had considered to sign up for a STEM degree after involvement in Arduino lessons, increased to 60%, as shown in Figure 7.

Although the participating students indicated that their STEM interest is stronger in the subject of Math, they rated learning programming the highest when asked what they learned the most in Arduino learning process (refer to Figure 6). It could be due to the nature of Arduino that has strong emphasis on programming skills for developing a workable prototype in which hardware and software interact together. It was interesting to point out that the students highlighted the skills in creativity and critical thinking as well as teamwork or collaboration as one of the areas that they learned significantly, which ranked second after programming skills. Arduino group assignment tasks could enhance students' learning of teamwork or collaboration, as well as communication skills whereby they talked about their ideas, brainstormed in group and negotiated to reach consensus (refer to Figure 15). This is because educational Arduino assignment focused

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on group work, project-based learning and problem-based learning. The results on the students' degree education choice show that the students are interested in pursuing STEM-related degrees (refer to Figure 7).

All in all, the results indicated positive impacts on their Arduino learning experience. 4Cs in 21st century can be developed through Arduino learning process in group projects. In addition, students' personal characters can be developed through learning Arduino. This is because the completion and the success in making Arduino projects instil students with a sense of achievement and boost their self-esteem; empower self-motivation and confidence; and cultivate determination and patience. The time is ripe for a new way of learning and developing our students' life skills. Both competency and character quality are life skills that are best developed through building projects, solving real life challenges and entering competitions. It was a joyful moment to see the students to get their first LED lit up and share the proud moment when their prototypes made an impactful contribution to the society.

From the questionnaire's analysis, it was noticed that only a minority of students (38%) agreed and strongly agreed that they were motivated to continue their studies in STEM programmes due to motivation from learning Arduino (refer to Figure 25). This might be due to the limitations of the time and Arduino kits available in the laboratory. These constraints required the students to share and/or take turns to use the Arduino kits. Thus, some students might not have sufficient time to explore other functions of Arduino.

CONCLUSION

Arduino is a key tool to learn new things for everybody. Arduino is proven as a great teaching and learning tool to promote STEM interests among students. It is highly recommended for teachers and lecturers to use Arduino to re-ignite the students' passion and revive their curiosity and eagerness to learn and explore. The hands-on, project-based learning experience provides long-lasting impacts on students' learning and motivation to further explore STEM-related degrees. UCTS is committed to promote STEM learning through educational lessons and maker events among students where learning is inspired, values are developed and curiosity is nurtured. Both FIA and FIS programmes for session 2017/2018 as the pilot study have provided the evidences that Arduino has positive impacts on participating students' learning of STEM as well as necessary 21st century skills to be successful including collaboration, communication skills, creativity and critical thinking skills. Arduino lessons which started in 2017 with 5 sets of Arduino has grown to 20 sets currently to benefit more students. As the number of students is increasing, it is hoped that more resources will be made available as well. FIA students were also given the chance to learn Arduino and were motivated to pursue STEM-related degrees. Making Arduino more accessible to students allows them to have more time and opportunities to explore on Arduino. To advance the objectives of promoting STEM, Arduino learning exposure has recently started to ignite among secondary schools through events and club activities via government initiatives. We believe Arduino provides valuable impacts on the education of the next generations, by advancing technological awareness and potential among young people. As for future work, this set of questionnaire can be applied to different cohorts of students to understand the students' learning and perception towards Arduino.

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