Introducing Arduino as an Effective Online Distance Learning Tool in Final Year Project for Chemical Engineering Student

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Abstract

The Covid-19 pandemic crisis has transformed project-based education into virtual lab and non-experimental work. Student final year project (FYP) course particularly is in critical since it has bigger credit, involves more skill set development and conducted in two semesters. In this work, we highlighted the implementation of Arduino in FYP where the main objective of the work is to investigate the effectiveness of Arduino home based final year project for chemical engineering student's cognitive, psychomotor and affective skills. Comparison on learning satisfaction, obtainment of student skills and reflection from both student and examiners were thoroughly discussed. Surveys showed that student were reluctant to carry out the project in the beginning; however, they began to show more interest on the project as they started to understand the basic principle of Arduino operation. Both students and the examiners agreed that Arduino-based project had given significant impact on student cognitive skills at the level of *Application*, *Analysis*, *Synthesis* and *Evaluation*. On top of that, the psychomotor and affective skills were simultaneously and successfully developed in the remote learning process. It is evident that the proposed Arduino home-based FYP is affordable and effective for the development of student skill sets despite being supervised virtually.

Keywords: Online learning, final year project, project-based learning, Arduino, constructivism.

Introduction

The pandemic has affected and changed the landscape of higher education atmosphere. Globally, teaching and learning process is obliged to be implemented virtually and this triggered serious concerns on the readiness and effectiveness of the delivery and acceptance. Engineering courses suffered critically from this occurrence. This is especially in worrying state for courses involving practical sessions that normally require face-to-face interactions such as laboratory work and final year project (FYP). A Final Year Project (FYP) is an academic task and/or a small investigation work carried out by a final year student that is formulated specifically to solve a complex research-oriented engineering problem over the course of a year (Gusau et al., 2019; Tien et al., 2015). Engineering accreditation bodies worldwide has made such a project a compulsory requirement for any engineering undergraduate education programs (Tien et al., 2015). Although such project needs to be completed individually by every undergraduate student, it still requires supervision from an expert which in this case, the professors in the higher learning institute. Clearly, FYP is an essential two-way teaching-learning process. First, it is an opportunity for the student to put all the skills and knowledge he or she has acquired throughout their studies into practice and thus, solving real life problems (Gusau et al., 2018; Tien et al., 2015; Uziak, 2015). Secondly, it is also a chance for the educators to identify the achievement of each student in the content of knowledge gained during their studies and obtainment of relevant graduate attributes (Tien et al., 2019; Uziak, 2015).

Given the significance of such project, it must be carefully designed such that it is consistent with the outcome-based education methodology that enables the student to acquire the desired cognitive, psychomotor and affective skills (Gusau et al., 2018; Isa et al., 2020; Tien et al., 2019). Generally, FYP projects are structured to direct the student towards achieving the problem-solving skills (cognitive), demonstrates the capacity to utilize modern equipment (psychomotor) and developed a good communication skill through their oral presentation and thesis writing task (affective) (Gusau et al., 2019; Isa et al., 2020; Tien et al., 2019). This has never been an issue in the higher learning institution until the pandemic crisis commenced. Traditionally, students received their respective project title from the appointed supervisors and work to meet the project objective in a designated research oriented laboratory (Tien et al., 2019). However, due to the rising cases of COVID-19 pandemic, can the same level of achievements and commitments be achieved from both, the students and the supervisors? In Malaysia, statistic shows that the number of cases has raised to an alarming stage and forces the government to announce a strict movement control order (Singh et al., 2020). Such ruling has a direct impact on the execution of student final year project. Students are no longer allowed to go to the laboratory (Abdullah et al., 2020) and therefore, caused a major problem for engineering students who greatly depends on high-end machinery/equipment in their projects. Moreover, learning environment has now shifted to online education as opposed to the classical face-to-face project supervision (Fidalgo et al. 2020).

Online learning or emergency remote learning is an education that takes place over the internet i.e. a type of distance learning mainly carried out through video conferences, live chatting, streaming, etc. (Sun and Chen, 2016). In the context of FYP, abrupt changes to such e-learning surroundings limit the resources and options to the type of home-based project that have to be done by the students. Efforts have been made by professors in the higher learning institution to adapt to this new paradigm whereby choices are limited to non-experimental research such as simulation work, mathematical modelling, theoretical review study, and/or surveys-oriented research work (Arriafdi et al., 2021; Li et al. 2020; Sultana et al. 2017; Yaacob et al. 2020). Whilst this may fulfil the basic requirements of FYP projects but another issue arises; this sort of project is not really the main forte for engineering students where majority prefer hands-on experimental study. Students are wary on how such projects would develop their cognitive skills. Proceeding down this path especially for those who unwillingly participate would only build-up a negative mind-set for which students are only doing it for the grades and not because they are motivated by the obtainment of specific set of skills and knowledge prior to the completion of the project. By focusing on non-experimental research, the psychomotor skills of the students are not developed and not there to be assessed.

Alternative solution to this problem is to promote the use of Arduino as a tool for engineering student home-based final year project. Arduino is an open-source data acquisition device that could communicate with various sensors and actuators (Bada et al., 2013; Kurelovic et al., 2020; Zainal Alam 2020). It operates on Windows interface and merely cost about RM 30-45 per piece (USD 7 to 11). Coding for Arduino programming are easily obtained from the internet and do not require any software licensing to operate (Bada et al., 2013; Kurelovic et al., 2020; Zainal Alam 2020). Moreover, to certain extent, Arduino can also be linked to the internet and thus, could entice attractiveness of online education. Student can create a project that produces real-time data that is readable not only by the operator but also by anyone that have access to the internet or in other words; the development of IoT projects (Bada et al., 2013; Kurelovic et al., 2020; Zainal Alam 2020). Despite the advantages offered, Arduino is only widely applied by electrical engineering majors i.e. either in their teaching-learning curriculum or as part of their FYP (Husain et al., 2016). Lack of training and exposure by both professors and students of non-computer (or electronics) background could probably be the main reason why such research/educational tools such as Arduino is not extensively utilized by chemical engineering majors (Gunasekera et al. 2018; Reggio et al., 2020; Zainal Alam, 2020). Furthermore, given the choice; majority of chemical engineering students would rather opt for lab work with close supervision from the professors than to independently create their own prototype as their FYP. This limitation needs to be highlighted and solving it becomes the main driving force for the work carried out in this paper.

The aim of this paper is to investigate the effectiveness of Arduino home based final year project for chemical engineering student's cognitive, psychomotor and affective skills. Chemical engineers are technically engineers who involved extensively on production processes in the field of chemical related industry/sectors. Their main task included (but not limited to) process plant design, project cost estimation and scheduling, and handling of a variety of machinery/equipment in production of specific chemical (or biochemical) products. Introducing the basic of Arduino operation as part of their training process would indeed be beneficial. As a result, chemical engineers could then expand their expertise to the field of design and implementation of various process automation which can be applied significantly in any chemical based plants. In order to further justify the outcome of this work, comparison on learning satisfaction, obtainment of student skills and reflection from both student and examiners will be thoroughly discussed as well. Assessment on the study were made qualitatively (questionnaire, survey, and reflection) and quantitatively (interviews and student presentation marks). The paper is formulated to specifically answer the following research questions:

- Would Arduino platform be suitable to be utilized by chemical engineering major –who knows so little about Arduino – as a tool in their home-based FYP?
- Would Arduino be an effective online distance learning tool for self-learning and also for development of higher level student skills (cognitive, psychomotor and affective).

The whole idea is to train the chemical engineering based students to utilize Arduino for their FYP without the need to depending on what is available in the lab and supervision can be carried out using any online video conference platform. This way, the FYP can indeed be conducted online i.e. some kind of do-it-yourself (DIY) Arduino rig from home. Interestingly, such project can also be done face-to-face when there is more restriction related to the pandemic. The paper reported how we conducted the Arduino-FYP for chemical engineering students and assess their performance.

Application of Design

Course Description

The FYP is a core component for chemical engineering program in the School of Chemical and Energy Engineering, Universiti Teknologi Malaysia. It is regarded as an important capstone course. Each project is supervised by a member of the faculty and the outcome of the project is evaluated through written reports and oral presentations. Finding a supervisor for FYP can be a challenging task; nonetheless, it has become a general practice where FYP coordinator will announce number of project suggestions made by the member of faculty to the students. Appointed supervisors are responsible to advise students on any technical aspects of the project. It is also their job to assess the credibility of the chosen project and assist the student wherever is needed prior to the completion of the project.

FYP is a 4-6 credit hours course that is offered to the final year students and typically carried out over a one-year period (or two semesters). In the first part of the project (FYP I), students need to construct a brief project proposal that consisted of relevant background references (literature review on keywords associated to the project), project objectives and planning on how they intend to meet those project objectives. Also, it is the choice of the student to conduct preliminary experimental work to generate proof-of-concept data for the project. On contrary, FYP II (i.e. the second part of the project) will involve more excessive experimental work in which student will work aggressively to produce more data for their thesis. Student will start to analyse, validate and interpret their findings.

This paper will focus solely on the development and output of FYP II. FYP II is a project based learning (PjBL) and the general learning outcomes are as follows:

Learning outcomes	Assessment
Identify project objectives and scope (*Cognitive*)	Thesis report & Oral presentation
Perform literature review & background check (*Cognitive*)	Thesis report & Oral presentation
Design & carry out experimental work (*Cognitive & Psychomotor*)	Thesis report & Oral presentation
Justify & interpret results/ findings extensively (*Cognitive & Psychomotor*)	Thesis report & Oral presentation
Derive conclusion & recommends future work (*Cognitive & Psychomotor*)	Thesis report & Oral presentation
Show originality & practice moral ethics (*Affective*)	Thesis report
Communicate effectively through oral and writing (*Affective*)	Thesis report & Oral presentation
Life-long learning (*Cognitive*)	Thesis report & Technical paper
Work independently and confidently (*Affective*)	Thesis report & Oral presentation
Capacity to plan and manage research work (*Affective*)	Logbook & Oral presentation

The execution of movement control order due to the rising cases of COVID-19 pandemic has caused a bit of a hassle in the teaching-learning process of the FYP. Nobody is allowed to conduct any work in the laboratory and FYP must be completed via online distance learning approach. Both supervisors and students have raised some concerns due to this unplanned situation. Among the issues associated to implementation of FYP online included:

- Limited options for the type of FYP for the students. Many decided to go for simulation work and/or theoretical study work.
- Poor internet connectivity prevents sufficient communication between supervisors and students
- Software licensing prevented students from using necessary software for modeling and simulation work
- Lack of motivation and/or idea in creating home-based projects with limited resources.

Theoretical background

Students involved in this project have undergone 3 years of formal fundamental chemical engineering education. Hence, they are expected to apply their problem solving skill via the application of knowledge they gained earlier. To approach this scenario, Constructivism Theory is adopted. In general, constructivism theory involves the building-up of knowledge by learners through real-life action, hands-on experiences and any previous formal learning. Knowledge is effectively gained whilst dealing with a real-world and authentic problem (Jumaat et al., 2017). FYP is a project-based learning that is in-line with the constructivism approach. Teaching and learning activities (including evaluation) of FYP are associated to the development of specific learning outcomes (Jumaat et al., 2017; Roessingh and Chambers, 2011). Each project will trigger student constructive investigation where it includes inquisition, problem solving, decision making, determination and active engagement with the supervisors (Jumaat et al., 2017; Roessingh and Chambers, 2011).

In this work, constructivist principles is incorporated in project-based learning by designing the FYP to focus on authentic or real-life problem that is closely related to their respective engineering program. Moreover, students are required to solve a specific task using a tool and/or technology whereby in this context, Arduino is proposed. Jumaat et al. (2017) highlighted that the use of technology in a project-based learning would sharpen students' problem solving skills. Technology adoption such as Arduino is regarded as educational tools that would assist students construct their knowledge in a real-world setting.

Course Description

Face-to-face meetings and lab work is no longer feasible because of the restriction in the movement control order ruling at the point where this paper is written and since the past 16 months. Due to this unavoidable circumstance, online learning platform is the main settings for the proposed home-based FYP project using Arduino. Since FYP topics related to Arduino is rather new to our targeted chemical engineering students (having no or very little knowledge on Arduino) and also to prevent any research work on non-technical topics, suggestions for Arduino home-based FYP topics were made by the supervisors.

Upon receiving topics for their projects, students had about 14 weeks to complete it. In the first four weeks, video conferencing with the supervisors were organized at least once a week via Google Meet or Webex. Discussions were also held using emails and/or WhatsApp platform. These online meetings were essential to discuss project progress and opportunities for the supervisors to help students understand the scale of the project. Students were advised to do in depth reading on Arduino and started to design the necessary circuit and hardware for the projects in the first two weeks upon initiation of the project. The work was also designed in such way that students would complete their rig within a month time prior to coding and troubleshooting phase which normally is the bottleneck for projects involving the use of Arduino. This is imperative such that students would have ample time to run the setup and generate sufficient data for their thesis between week 8 and week 12.

Once students started to actively engage in the project, frequency for online meetings reduced to once every two weeks. This is simply to let the students focus on the hands-on work rather than to let them ask too many questions about the subject. Students were also advised to record their weekly activities and/or any technical information they discovered in a project-related log book. That information would assist students on their thesis write-up. Students were strongly recommended to start their thesis writing right away while carrying out their work. This is because writing the thesis report is not difficult when students just finished up each milestone rather than to discuss and compiling it at the end of the semester. Finally, students submitted the first draft of their thesis on week 14 in order to allow sufficient time for supervisors to read it and suggest necessary improvements. Further discussion from week 14 onwards was simply about student preparation for their thesis presentation which was held in the week 16 of the semester.

Evaluation of Attainment of Cognitive Level & Project Based Learning

In this study, the effectiveness of the proposed Arduino home-based online FYP was evaluated qualitatively where data were acquired through survey, questionnaires, reflection and interviews. The first evaluation is on the students' project output and the learning process of each student. Evaluations on the student output were carried out in stages i.e. upon achieving each project milestones. Students presented their outcome during online meetings and assessments/recommendations were made based on the students' achievements. This is a type of formative assessment where it helps to track the progress of the PjBL and also help the students to reflect on their learning and its connection to the project objectives and the efforts made. Secondly, a questionnaire survey using multiple choice questions was used to assess student learning process with respect to their FYP progress. Details of the questionnaire are presented in **Appendix A.**

Investigation was also performed to study about student learning satisfaction and feedback on the project they participated in. This was done using Likert scale questionnaire. Details of the questionnaire used are given in **Appendix B and Appendix C**. These questionnaires were structured specifically to assess student responses about the project and to find out to what extent student was able to appreciate the project, Moreover, students were also required to give reflection on the things they have learnt from the project and comment weather such project would benefit them as an engineering student. Thematic analysis was performed on the feedbacks received in which important text/comments were first identified before grouping them into themes that are related to the research questions imposed for the activity (Azizan et al., 2018). In this case, suitability and effectiveness of Arduino as a tool in student home-based FYP could be analysed.

For evaluation on the achievement of the FYP learning outcomes, another set of questionnaire survey using multiple choices questions were given to the students after they have completed their final presentation of the project. The survey aimed solely at the development of student cognitive skills after completing the project. Details of the survey used are shown in **Appendix D**. Additionally, a brief interview was also conducted with the examiners (i.e. those who were appointed to evaluate the students' final presentation) in order to assess their perception on how the proposed Arduino home-based FYP had affected the students critical thinking. The set of question used for the interview are as follows:

COGNITIVE LEVEL – APPLICATION

1) In your opinion, does the student **APPLY** sufficient/necessary knowledge associated to engineering field in formulating the project methodology?
2) Is the student independently capable in **CONSTRUCTING** the hardware/software part of the project?

COGNITIVE LEVEL - ANALYSIS

1) In your opinion, does the student have the capacity to **COMPARE** suitable engineering theory with the practical work conducted?
2) Does the student have the ability to **IDENTIFY** and **ANALYZE** (or trouble-shoot) problems occur in the project?

COGNITIVE LEVEL - SYNTHESIS

1) In your opinion, does the student have the capacity to **DESIGN/FORMULATE** the hardware/software of the project with appropriate engineering elements independently?
2) Does the student have the ability to **RECOGNIZE** any issues pertaining to the project and recommend suitable improvement for future work?

COGNITIVE LEVEL - EVALUATION

1) In your opinion, does the student shows the capacity to **INTERPRET** the results of the project appropriately and creatively link it to relevant engineering knowledge?
2) Does the student have the ability to **EXPLAIN** the output of the work in orderly fashion?

A thematic analysis was also performed on the student reflection on the work given. A deductive approach was carried out to identify and/or search for repetitive keywords. Patent or keywords of interest in our analysis are the ones closely related to the development of student cognitive, psychomotor and affective skills.

The Results and Discussion

Students Output and Learning Process

The effectiveness of carrying out Arduino home-based projects as FYP on the development of student cognitive levels was investigated. Evaluation was performed on ten different projects that were carried out by Chemical-Bioprocessing students from Universiti Teknologi Malaysia (UTM) for the period of 2 years. Due to limited resources, it was decided early on that titles for the students FYP were restricted on the topics that are associated to online monitoring in the area of agriculture and basic engineering works. It was believed that these types of projects can easily be implemented at home and low cost. The student performance exceeded our expectations and some of the examples of Arduino home-based FYP implemented are shown in **Figure 1** where one of the FYP topics were on the online monitoring of energy input from the solar panel. The project is closely related to one of the sustainable developments goals (SDGs) i.e. the use of affordable and clean energy (SDG7). In this project, student built a data logger using Arduino to continuously monitor the energy generation (in DC voltage values) from a 100W solar panel. The student also investigated the effectiveness of using solar energy to operate a water pump for watering a back yard size home garden. The second FYP example is the establishment of monitoring of water flow and quality of an aquaponics platform using Arduino. Additionally, a 50W solar panel was utilized for the water pump operation as well. Both projects were fully funded by our team and the cost of each project was less than RM 200 (USD 48).

Figure 1. Output of FYP Arduino home-based projects where student work on the establishment of online monitoring of solar energy generation (left) and online monitoring of bench-top aquaponics platform (right).

Overall, all students participated in our Arduino home-based FYP projects undergone different stages of learning. Upon receiving their task (topic), students were a bit intimidated at first. This is because most of them did not have any experience with Arduino. The students were only taught about the basic of Arduino

(Kurelovic et al., 2020). Clearly, the students were lack of confidence to work on the project on their own. Initially they asked so many questions rather than to look for answers on their own. The learning curve on various aspects of the project is illustrated in **Figure 2**. In the first couple of weeks, we had to guide them and fully supported their work. Students found that they were unable to initiate the project. Nevertheless, it changes as the project progresses. Students started to build-up interest on the topic and started working on building their rig. The essential part of supervising this type of FYP is that we have to let them explore the project and allow them to realize the experimental setup on their own. 'Word-for-word' instructions are not necessary as most of the information needed for them to realize the project is available in the internet. Materials for the rig can be attained from local hardware store and coding for Arduino programming work can be learned from various open source platform (e.g. *YouTube*). It can be seen in **Figure 2**, students mind setting on the difficulty of the project they were working on changes significantly from 'extreme' to 'relatively easy' over the period of 14 weeks. Our hypothesis on the fact that there was a significant improvement on student mind setting and skill sets as the progress progresses from week 2 until week 14 was also confirmed statistically where results attained were compared using the two level independent-means t-test. Data showed that the result on the two groups tested (i.e. between week 2 and week 14) was significant in which the p-value is 9.555×10^{-21} ($p < 0.05$).

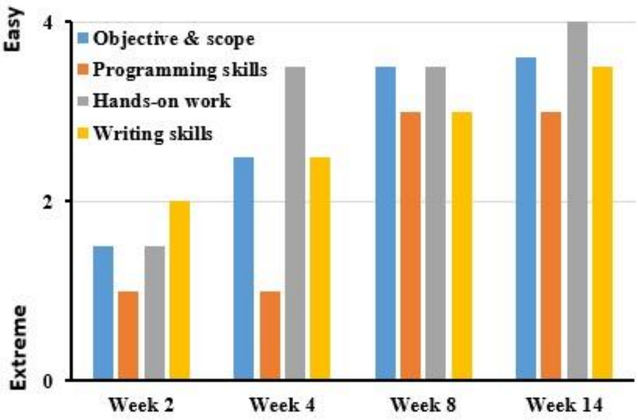

Figure 2. Summary of formative assessment to track student learning progress during FYP.

Student Learning Satisfaction and Reflection

Learning satisfaction depicts the student feeling and their reflection after the teaching and learning sessions. It can promote a positive environment and boost the student's morale if they enjoyed the process. Therefore, it is important to measure the student satisfaction on this hands-on Arduino project. **Figure 3** shows the summary of the assessment made on student learning satisfaction in working with Arduino home-based FYP. The first question in the questionnaire is about difficulty level on learning how to operate Arduino. Half of student (52%) agreed that learning Arduino was easy. This gave a positive impression on Arduino based project. The result from survey found that majority of student which was 84% of them did not prefer modeling work or simulation based project. It is aligned with the fact that 85% of the students were happy to participate in hands-on Arduino project. After 14 weeks completing the task given, 95% of the students found that learning Arduino is fun. Where, 85% of them strongly agreed that hands-on (DIY) project based could improve their skills as engineering student. All students agreed that they learned a lot from Arduino project. More than half of the students found that DIY Arduino based project is interesting and requires minimal supervision during completion of the task. Majority of them are happy to participate in this Arduino based project again in future and also, three quarters of the students will share their knowledge and findings with friends while working on the project.

Meanwhile, **Figure 4** summaries the assessment made on student feedback in working with Arduino home-based FYP. At the beginning of the project, there were mixed responses as whether the students have experience or not working with Arduino. It was found that 43% of the student did not have any experience with Arduino program. However, they think positively where majority of them reckoned that the assembling hardware/software was not difficult. They were willing to learn a new thing and need minimal supervision from the supervisor. Nearly 80% of them could solve technical problem and hands-on problem on their own. On the other hand, it was found that most of the students were not comfortable with algorithm thinking - where they have problem in coding writing and designing a program. This was probably a result from lack of practice after completing their fundamental courses in programming taken back when they were in their first year of their study. Despite of that problem, they still enjoyed to explore this Arduino project and passionately seeking solution to a problem that was given to them. Majority of them strongly agreed that they did not complete this hands-on Arduino project just for the grades, which is a pleasant feedback.

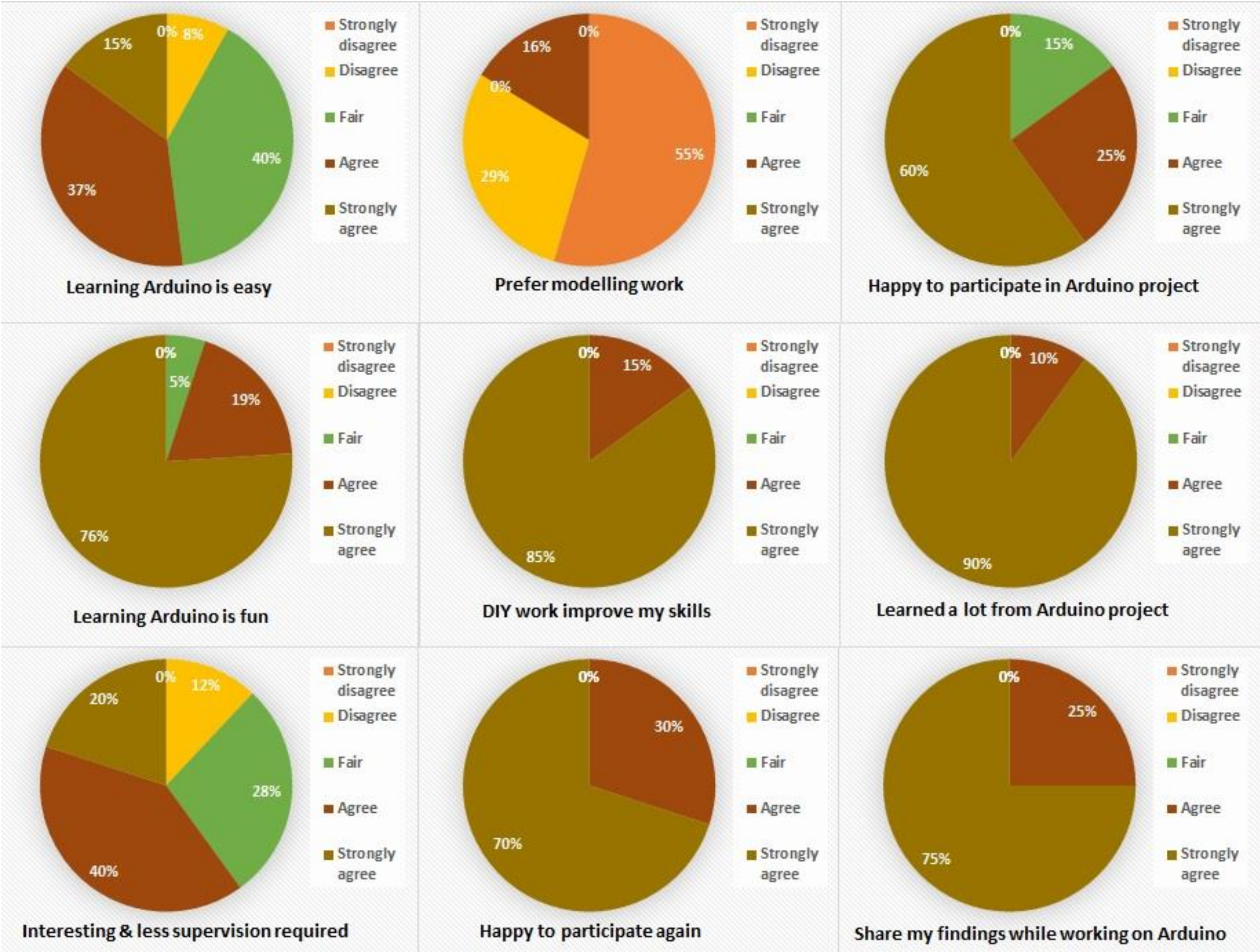

Figure 3. Student learning satisfaction in working with Arduino home-based FYP.

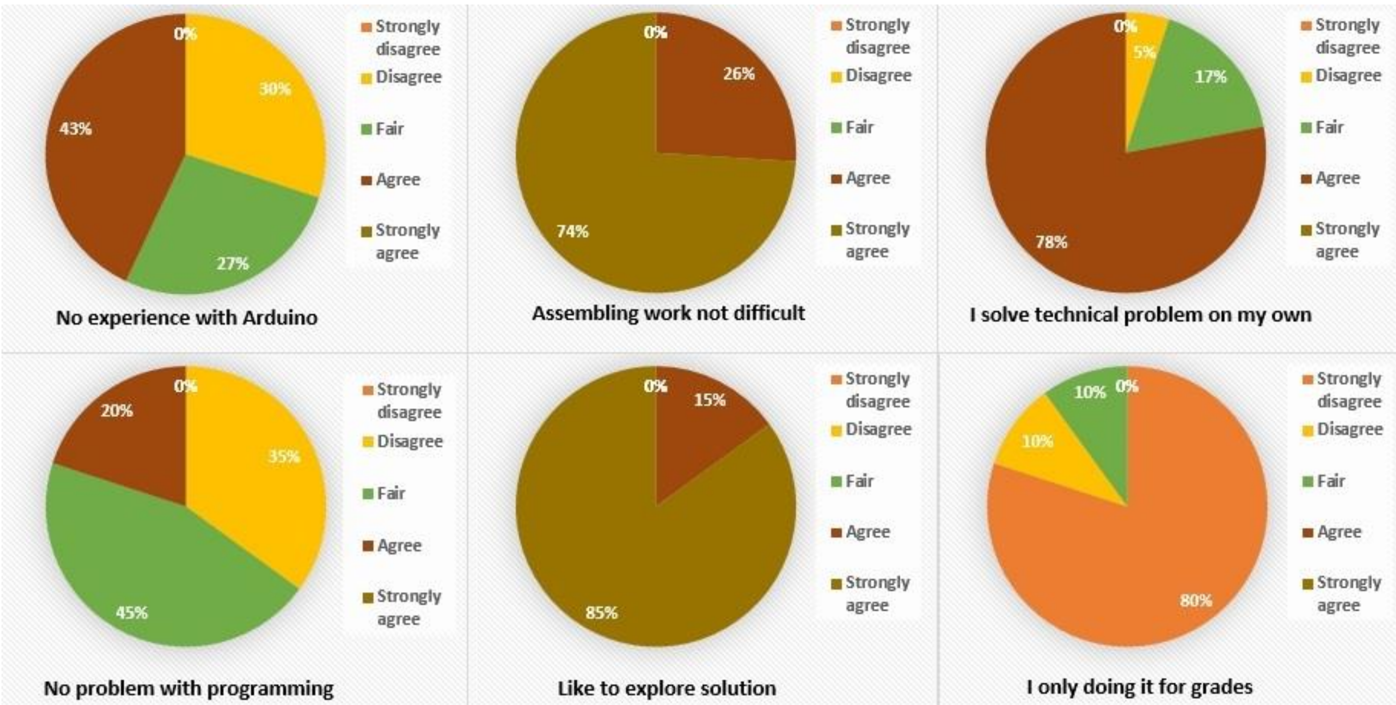

Figure 4. Feedbacks from students that worked with Arduino home-based FYP.

Table 1 shows the reflections of the students who participated in this study. It can be concluded that most of the students looked at this project as a new line of work (or subject) and the task is very challenging. It is difficult at first and they needed some time to digest the concept of Arduino. However, with only minimal supervision, they managed to overcome all the challenges and completed the project. This project fulfilled the learning outcomes which focus on work independently and confidently, which could encourage student's lifelong learning skill. At the end of the project, students enjoyed the task and explored new tools willingly by themselves. They reckon that this is useful for their future career and helps improved their hands-on skills. From **Table 1**, the skills attained by students based on the keywords can be quantified as follows -Cognitive: 16; Psychomotor: 11; and Affective: 15. The result indicates frequency the keyword that reflected to the specific skill domains category have been mentioned or indicated by the students. It is imperative to take note that in general Arduino based FYP project successfully managed to extract the core skills required for this course even though it was conducted remotely. Cognitively, students managed to deeply learn as they were able to apply, analyze, synthesize and evaluate their research work. While other FYP projects opted for non-experimental research that contributed zero psychomotor skills to the students, this Arduino based FYP project manage to yield psychomotor skills for its student. The affective skill domain which deals with emotional aspects such as feelings, values, appreciation, enthusiasms, motivations, and attitudes can also have been obtained from the inference of the student's reflection. Student 1 and 7 did highlight that they have prior knowledge and experience on working on Arduino; however other students did not mention anything about it. Other students may have indirectly used their programming skills knowledge from their first year to successfully bridge their comprehension on Arduino programing. These indicates the support and realization from the Constructivism theory.

Table 1. Reflections from the students about aspects they learned and benefited from the work.

Reflections	Keywords
Student 1 I have got some basics about Arduino and decided to do something a bit more complex. It is not so difficult and I managed to solve everything on my own with very little help from my supervisor. Got to learn new hands-on skill.	got some basics * complex [a] not so difficult [c] managed to solve [a] got to learn [a] hands-on skill[b]
Student 2 I really like it. A lot of independent design work though. Easy to gain knowledge because work everything from scratch.	like it [c] independent design work [a] gain knowledge [a] work everything from scratch [b]
Student 3 Not really my first choice. However, it gets interesting and I get to practice my hands-on skills. Have to be independent to make the project work.	gets interesting [c] get to practice / hands-on skills [b] be independent [c] make the project work [a]
Student 4 Nice project. Good for those who likes to design stuff. A bit challenging with coding.	nice project [c] design [a] challenging [c]
Student 5 Arduino project is really cool. Coding and hardware makes you good in hands on. Work everything on my own and sometimes difficult but good project.	really cool [c] hands on [b] work everything on my own [b] sometimes difficult [a]
Student 6 It needs a lot of hard work in the beginning but paid off in the end. Really like the work and very different from running typical experiments using complex equipment.	hard work [c] paid off in the end [a] like the work [c] very different [b]
Student 7 Arduino is very interesting project. Plus, I have learned a little bit about it in my second year. The project helps me to work independently, explore new tools and improve my hands-on skills.	very interesting project [c] learned a little bit [a, *] work independently [c] explore new tools [a] hands-on skills [b]
Student 8 Learned about Arduino before. Luckily have basics to can build my setup on my own with not much supervision. Enjoy it as I get to explore many new things and good hands on project.	Learned [a] before * build my setup [b] not much supervision [c] explore [a] hands on project [b]
Student 9 I was nervous when starting working on the project. Don't know anything about Arduino. However, was surprise everything can learn from internet and I built my setup using stuff from hardware store. I enjoyed the project.	nervous [c] can learn from internet [a] built my setup [b] enjoyed [c]
Student 10 It's a very good project. I managed to learn about new skills and new knowledge on solar and renewable energy.	good project [a] new skills [b] new knowledge [a] good for my future [c]

This is good for my future as engineer. Glad I picked this.	

[*] Constructivism Theory
[a] Cognitive
[b] Psychomotor
[c] Affective

Assessment on Development of Cognitive Skills

After completing the project, all of the students voluntarily filled-up the general survey form given to them. The surveys were conducted to assess the student on the development of specific aimed cognitive skills during this home-based Arduino FYP work. As previously described, four different levels of cognitive skills associated to FYP i.e. *Application*, *Analysis*, *Synthesis* and *Evaluation* were assessed in the survey. The results of the survey were analyzed and depicted in **Figure 5**. According to the results attained, majority of the students (i.e. more than 70 %) claimed that they have excellent achievement in the *Application*, *Synthesis* and *Evaluation* cognitive levels through the proposed FYP. The rest were convinced they had good accomplishment in the same levels. It is suspected that student direct involvement on the Arduino project has nurtured their skills on the matter.

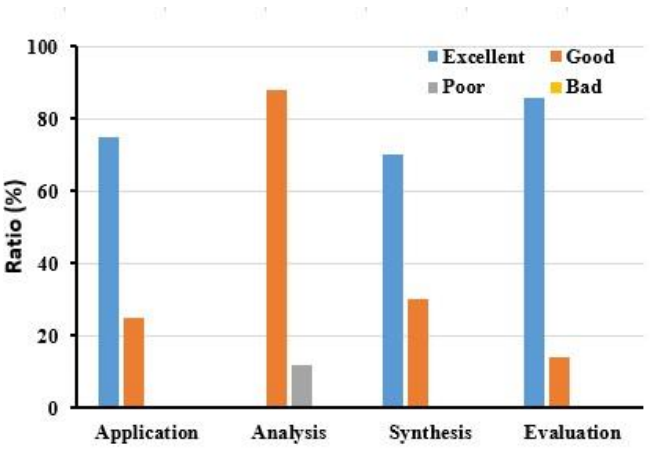

Figure 5. Summary of the general survey conducted to determine the development of student cognitive levels upon completing the FYP work.

Student designed their own rig based on their creativity. Ability to formulate and realize their own setup enabled them to reach the *Synthesis* levels. The '*Application skills*' were obtained through application of knowledge (gathered after searching through the internet for relevant information). The information is mainly about circuit diagram and coding prior to realize their setup. The final phase in building-up their rig was the troubleshooting stage where student evaluated the workability of their setup. Any problem occurring was solved independently and thus, allowing them to excel in the '*Evaluation*' cognitive skills. With high percentage (86%) of excellent achievement in evaluation skill which is the highest level of Bloom's taxonomy means, that most of the student are independently able (without help) to interpret the output of the project and make necessary comparison to evaluate its functionality after they have completed the design and create their own algorithm in the Arduino-based FYP.

Contrary to other cognitive levels achievement, students were less convincing on their achievement for the '*Analysis*' skills. About 88 % of the students have achieved good in analysis skill through Arduino home-based online FYP, which means, with some help, the students are able to identify most of the components/parts accurately and able to code/ trouble shoot a program properly. Only 12 % of the students have responded that they poorly perform in the analysis skill. This is probably because of lack academic background on electrical/electronic component and computer programming which made it a bit difficult for them to identify any components/ parts accurately and trouble shoot a program properly even though they receive help from their peers and supervisors. Nevertheless, this did not impose any major obstacle for the student in completing their project.

At the end of week 14, students presented their work to several examiners in a formal evaluation setting. After evaluation, we conducted an interview session with the examiners to get hold on their perception on how the Arduino home-based FYP had affected the student's cognitive skills development. Selected comments from the examiners are summarized in **Table 2**. Their comments were analyzed and relevant keyword related to the student skills developments were categorized accordingly. It was found that majority of the examiners expressed their satisfaction with student involvement in the Arduino home-based FYP as enjoyable and amazing project. While the FYP was carried out in home-based mode, most of the examiners found that the students were able to work independently and present their project in great details.

The examiners collectively agreed that the students working on the Arduino home-based FYP had achieved most of the important skills required. The cognitive skill levels assessed covered the application skill up to the highest level of Bloom's taxonomy, which is evaluation skill. However, examiners highlighted that the communication skills of students were average and require more practice for significant improvement. Students lack of confident in presenting the information about Arduino perhaps due to the differences in their academic background. It was also suspected that less training and time were spent on supervising the students on the best way to present their home based project which was done virtually (Webex platform). The fact that students dwelled in their home since the pandemic is also believed to influence the student's emotion, communication and presentation skills as they interact normally with each other drastically lesser compared to when they were face to face in university. Collaboration of both supervisors and FYP coordinator are required in helping and supporting student's to overcome issues that require improvements.

Table 2. Examiner's comment on the performance of student's working on Arduino home-based FYP.

Comments from examiners	Keywords
It seems that these students really enjoyed working with Arduino. They can surely translate what they have been working on and has no problem linking their findings with actual theory. Everything was built by themselves and definitely have achieved a solid cognitive level of synthesis and evaluation.	really enjoyable [c] can translate what they have been working on [a] linking their findings [a] built by themselves [b] achieve solid cognitive level [c]
They did an amazing FYP work. The students did manage to describe every details of the project they worked on. It shows the project has trained them on achieving cognitive level of application, synthesis and a solid analyses level.	describe every detail [a] the projects have trained them [a]
They can definitely present their work because they work on their project independently. They understood and knows very well on how to apply (and evaluate) basic engineering knowledge even though Arduino is very new to them. Needs more practice in their communication skills.	present their work [b] work on their projects independently [a] understood and knows [a] how to apply [b] need more practice [b]
The students did understand everything they built. Some still needs to do a bit more reading. Communication skills on knowledge sharing is still average. Nevertheless, the FYP surely improved their cognitive levels of analyses, application and evaluation.	understand everything [a] Communication skills [b] Improved their cognitive [a]

[a] Cognitive [b] Psychomotor [c] Affective

From **Table 2**, the skill domains attained by students based on the keyword gathered from examiner's comments can be quantified as follows - Cognitive: 8; Psychomotor: 5; and Affective: 2. In general, the examiners acknowledged the psychomotor domain achieved by the student's FYP project. This finding is consistent with previous discussion on **Table 1** earlier. Since the evaluation is always more on checking of student's cognitive ability, examiners commented more on this while the affective domain was low because this was not the main focus of the formal evaluation. Overall, findings gained from this study provided useful information that proved the effectiveness of Arduino implementation on the home based FYP for the development of chemical engineering student's cognitive, psychomotor and affective skills in the context of remote learning. Arduino platform can be utilized by chemical engineering major even they knew very least about Arduino.

Conclusion

The suitability of applying Arduino in non-electrical (electronic) engineering students FYP and its effectiveness as a home-based project for development of final year student cognitive skills was investigated. Surveys show that student were reluctant to carry out the project in the beginning (due to lack of knowledge and skills on Arduino); however, they began to show more interest on the project as they started to understand the basic principle of Arduino operation. Students did not show any major issues in assembling the hardware needed in realizing their rig. Coding of the Arduino setup posed some challenges but students managed to overcome it through online resources and sharing of knowledge with their peers. Both students and the examiners agreed that such Arduino-based project had given a significant impact on student cognitive skills at the level of *Application*, *Analysis*, *Synthesis* and *Evaluation*. Apart from this, student also showed creativity in solving problems pertaining to the project and less relying on their supervisors. Clearly, not only the proposed Arduino home-based FYP is affordable but it also supported the idea of online distance learning that offers a valuable skill sets for the student.

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Appendix A. Rubrics of the questionnaire used to evaluate student learning process

	EASY	MODERATE	DIFFICULT	EXTREME
Defining project objective & scope of work	Able to determine objective and define the boundaries of the project without any supervision.	Able to determine objective and define the boundaries of the project with very minimal supervision.	Would require significant amount of help from the supervisor to determine project objective and scope of work.	Unable to formulate the project objective and scope. All information comes from the supervisor.
Programming skills	I have learnt about such programming before and have a strong basis to work on it independently.	It is a bit out of my forte but willing to learn about it from the open sources.	It is a little bit confusing at times but with constant help from the supervisor I can manage.	This is completely beyond my capacity and need constant help and supervision.
Hands-on/ practical work	I do not have any issues assembling the setup and get my hands dirty.	It is a bit challenging but with minimal supervision, I can manage.	This is completely beyond my capacity and need constant help and supervision.	Irrelevant. No practical / hands on work needed.
Write-up: Results & discussion	I have no issue in presenting my data and discuss my results in the thesis.	It is a bit challenging but with the guidance from my supervisor and information from the literature I can manage.	I am not able to do this without some assistance from my supervisor.	This is completely beyond my capacity and need constant help and supervision.

Appendix B. Likert scale questionnaire used to evaluate student learning satisfaction on the Arduino home-based projects they participated in.

1. Learning how to operate Arduino is very easy.	1	2	3	4	5
2. I would prefer to do modelling or simulation based project	1	2	3	4	5
3. I am happy to participate in a project involving Arduino.	1	2	3	4	5
4. Learning how to operate Arduino is fun.	1	2	3	4	5
5. Hands-on and DIY work does help me to improve my skills as an engineering student.	1	2	3	4	5
6. I learned a lot from this Arduino based project.	1	2	3	4	5
7. DIY Arduino based project is interesting and do not requires much supervision.	1	2	3	4	5
8. I would be happy to participate in this Arduino based project again.	1	2	3	4	5
9. I shared my knowledge and findings with my friends while working on the project.	1	2	3	4	5

(1-STRONGLY DISAGREE, 2- DISAGREE, 3- FAIR, 4-AGREE, 5-STRONGLY AGREE)

Appendix C. Likert scale questionnaire used to evaluate student feedback on the Arduino home-based projects they participated in.

1. I do not have any experience working with the subject.	1	2	3	4	5
2. Assembling the hardware/software is not a problem for me.	1	2	3	4	5
3. I solve technical and other hands-on problem on my own.	1	2	3	4	5
4. I have no problem with algorithm thinking and programming (coding).	1	2	3	4	5
5. I like to explore and find solution to a problem related to the project.	1	2	3	4	5
6. I found learning this type of project is a bit frustrating and I am only doing it for the grades.	1	2	3	4	5

(1-STRONGLY DISAGREE, 2- DISAGREE, 3- FAIR, 4-AGREE, 5-STRONGLY AGREE)

Appendix D. Questionnaire survey used to assess the development of student cognitive skills upon completing the Arduino home-based online FYP.

Cognitive levels	Excellent (4)	Good (3)	Poor (2)	Bad (1)
APPLICATION Apply engineering knowledge learnt in class to **construct** circuit and hardware needed for the project.	I am able to apply basic engineering knowledge to construct the circuit/ hardware accurately with no errors and do not need any help.	I am able to apply basic engineering knowledge to construct the circuit/ hardware accurately with few or no errors and may need some help.	I am barely able to apply basic engineering knowledge to construct the circuit/ hardware accurately even with some help.	I don't know how to apply basic engineering knowledge to construct the circuit/ hardware accurately even with some help.
ANALYSIS Trouble shoot the workability of a project/equipment constructed and **identification** of coding and parts.	I am able to identify every components/ parts accurately and able to code/ trouble shoot a program properly without help.	I am able to identify some but not all the components/ parts accurately and able to code/ trouble shoot a program properly with some help.	I barely can identify any components/ parts accurately and code/ trouble shoot a program properly even with help.	I can't identify any components/ parts accurately and code / trouble shoot a program properly even with help.
SYNTHESIS Ability to **design** a functional device/project to perform a specific task. Integrate training and various resources to solve a problem.	I can design and create my own algorithm properly and project without help.	I can design and create my own algorithm properly and project with some help.	I can barely design and create my own algorithm properly and project even with some help.	I can't design and create my own algorithm properly and project even with some help.
EVALUATION				

Make judgements and **interprets** on the output and the functionality of the project.	I am able to interpret the output of the project and make necessary comparison to evaluate its functionality without help.	I am able to interpret some of the output of the project and make necessary comparison to evaluate its functionality with some help.	I am barely able to interpret the output of the project and make necessary comparison to evaluate its functionality even with some help.	I can't interpret the output of the project and make necessary comparison to evaluate its functionality even with some help.