Improving Learning Experiences with Project Development and Problem-Solving Using Microcontroller – A Case Study

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Abstract

This paper presented an innovative teaching practice to promote problem-based learning via the Internet of Things (IoT) and Arduino microcontroller workshop. This educational research evaluates the participants' improvements in terms of the knowledge, confidence level and motivation. The participants included multi-disciplinary engineering students, who have enrolled in Electrical Systems (ELEN1000), whereby they completed all given tasks in teams and within a limited time. At the end, a total of 91 respondents' feedback was accumulated and analyzed via descriptive, *T-test* and ANOVA analysis. *T-test* 1 (p = 0.08135) found that the workshop improved participants' excitement. *T-test* 2 (p = 0.1323) explained that the workshop activities help to visualize the learned knowledge. Nevertheless, *T-test* 3 (p = 0.02) implied that the developed confidence level did not improve respondents' capability to generate spontaneous ideas. *T-test* 4 (p = 0.15999) highlighted that respondents are impressed with their capabilities after viewing the results. ANOVA Test 1 revealed that knowledge visualization significantly enhanced participants' confidence levels; however, it was insufficient to substantially improve their ability to generate spontaneous ideas for problem-solving. These findings suggest the need for additional activities that expose participants to a broader range of IoT applications. Overall, all respondents reported highly positive perceptions of the workshop and expressed inspiration to utilize microcontrollers in their future projects.

Keywords: internet-of-things, microcontroller, descriptive, *T-test*, ANOVA.

Introduction

Nowadays, there is a significant shift in learning and teaching practices of tertiary education by adopting more practical components integrated into students' learning opportunities, supported by advanced technologies. This is in accordance with the students' expectations for education practicability (Thien et al., 2022). The students' expectations are apprehensible in current practices, which are more focused on teaching knowledge and principles. Applications of knowledge began to gain attention from a few Malaysian universities. Moreover, there is a dramatic increase in engineering courses to incorporate digital technologies such as microcontrollers and Internet of Things (IoT) applications. Alvarado & Maestre (2019) constructed a replica of the famous weapon (lightsaber) of the Star Wars movie using a microcontroller. Afonso et al. (2021) adopted an innovative teaching-learning method for the automated control of robotics using microcontrollers.

Improving learning experience via applying the learned knowledge is an idea that can be a drawback to Kolb's education philosophy in 1984. Practicing the learned knowledge enhances the experience, whereby new knowledge is created through the transformation of experience (Kolb, 1984, p. 38). He presented a learning cycle that covers Concrete Experience, Abstract Conceptualization, Reflective Observation, and Active Experimentation. In the context of microcontroller, learning experience and knowledge transform can be materialized via developing circuits, deepen understand of its theory and further improve the design.

Few educators suggested that practical experiences can be consistently explored via project-based learning because this allows contemporaneously to engage the learning processes with other soft skills. Dunai et al. (2017) applied traversal skills consisting of scheduling, organizing, structure design, agile communication, teamwork and presentation for the developed project. Swart & Hertzog (2018) demonstrated the connection of microcontrollers with various sensors in an academic workshop. All literature above applied comprehensive approaches and it is good to have a few perception studies on the designed tasks; thereafter, they could be studied and referred to by other educators.

This paper recommends implementing an innovative teaching practice by applying digital technologies in an organized IoT and Arduino microcontroller workshop. This educational research evaluates the extent of improvements in terms of participants' knowledge, confidence level, and motivation after completing the assigned tasks. In common, students are relatively weak in applications due to a lack of hands-on skills. Some students were unable to answer consistently application related problems of the microcontrollers and IoT consistently in their assessments. From the students' feedback comments, more application examples are required to study and practice this topic. In light of this, a series of innovative workshops was planned by the unit lecturer to stimulate conceptual knowledge learning by providing students with the opportunity to develop projects from scratch or solve the hidden errors in both hardware and Integrated Development Environment (IDE) programming.

Microcontrollers such as the Arduino series are an open-source embedded system used for data acquisition and control applications via interacting with sensors and actuators. The microcontroller is relatively inexpensive and is being adopted in university courses (El-Abd, 2017). Arduino microcontroller is compacted with an 8-bit ATmega microprocessor, analog & digital IO pins, serial communication modules, and other interface functions. Recktenwald & Hall (2011) explained that the microcontroller realm has many advanced technologies in real-life applications and is adaptable to IoT technologies. Students gain invaluable knowledge and know-how to develop projects on a breadboard, operating with the Arduino microcontroller.

This paper presents a survey study of an innovative workshop, which provides project tasks related to the application of the Arduino microcontroller. The workshop focuses on multi-disciplinary engineering students who are enrolled in the Electrical Systems (ELEN1000) at the institution. Students are invited as participants and respondents voluntarily. The participants work in a team to develop application functions from scratch by using the Arduino and ESP8266 microcontrollers. Each task in the worksheet instruction is a dialogic scaffolding approach (Gutierez, 2021) with a few hidden errors for both hardware wiring and IDE programming. Participants discuss and incorporate all ideas from previous tasks to develop a new project from the available components. The paper is organized into various sections. The literature review explains the literature on microcontrollers in real applications and education. Methodology describes the experiment design, questionnaire model and analysis methods. This is followed by analysis and results that analyze all the feedback with descriptive, *T-test* and ANOVA analysis. Discussion further elaborates on the outcomes of all analyses. Last but not least, the conclusion of the findings with suggestions was described and the improvement in the workshop activities was discussed.

Literature Review

There are literature works on incorporating the microcontroller in teaching practices. Recktenwald & Hall (2011) introduced a hands-on curriculum to learn the microcontroller. Rosen et al. (2014) provided a preliminary skill to reflect the learning of various engineering knowledge and applications. Carlotta (2016) improved the hardware equipment by designing LEGO MINDSTORMS projects using Arduino microcontrollers. Agatolio & Moro (2017) promoted an Arduino microcontroller-based robot as an interactive learning tool. Husni & Purnama (2020) adopted a data accumulation function to an electric physics experiment board for Science, Technology, Engineering and Mathematics (STEM) education media. On the other hand, AL-Yoonus (2019) encouraged students to develop microcontroller-based projects with reusable electronic components. Besides, Istiantara et al. (2019) researched the extension of the microcontroller-based straight motion practicum media to improve students' project management and communication skills.

Arduino microcontrollers are high feasibility adopted with the industrial-based projects. Balaji et. al. (2019) developed a consistent monitoring function of the HT motor systems and controlled them wirelessly by the ESP8266. In addition, Haq et al. (2020) developed a cost-effective ultrasonic tide-measuring device by embedding a microcontroller, ultrasonic sensor and Global Positioning System (GPS) module with the IoT to upload and monitor real-time parameters on the website.

Mishra et al. (2018) incorporated an Arduino microcontroller into the cloud to monitor irrigation water usage for optimized crop growth. Veeramanickam et al. (2022) presented parking detection and monitoring by using an IoT platform at college campuses. Chew et al. (2021) and Benny et al. (2024) applied IoT principles to a Proportional-Integral-based light control system and smart detectors at the high-risk working environment, which showed that IoT technologies are well-adapted to practical applications. Moreover, Ahmad et al. (2019) concluded that participants successfully demonstrated conceptual scientific understanding by participating in microcontroller-related experimental activities. The mentioned projects significantly inspire research motivation among authors and optimize their learning experiences.

Methodology

The methodology session explains the Design of Experiment (DOE). In addition, this session also discusses statistical analysis approaches via Descriptive, *T-test* and ANOVA.

Workshop Flow

Figure 1 illustrates the flowchart of the experiment design. Participants will perform the project tasks based on the worksheet and then to test the developed functions. After the workshop, all participants were required to fill out a set of survey questionnaires. The data from the questionnaire are then analyzed via descriptive, *T-test*, and ANOVA analysis.

Questionnaire

The survey questionnaire accumulates participants' feedback after completing their tasks. The feedback is essentially reflecting how efficiently the designed workshop improves their conceptual knowledge, confidence level and motivations and others when learning the microcontroller and IDE programming. Table 1 depicts the questionnaire model for the innovative workshop.

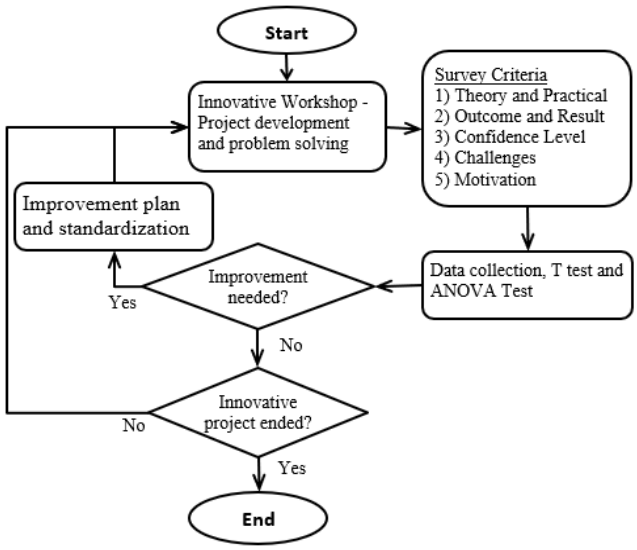

Figure 1. Flowchart - Design of experiment

Table 1. Case study questionnaire list

Criteria	Question	Content
Knowledge & practical	A	I am excited to practise while learning the microcontroller and IDE programming knowledge.
	B	The workshop activities are systematically designed to learn principles, concepts and develop ideas when studying the theory.
Outcome/ Result	C	The workshop activities allow me to immediately visualize the learned knowledge after completing each task.
	D	I have enhanced my understanding of the learned knowledge via practical activities.
Confidence level	E	The workshop enhances my confidence level via step-by-step problem-solving for IoT and microcontrollers.
	F	The workshop improves communication and co-operation among teammates while completing practical tasks.
New Challenge	G	The workshop enhances my capability to produce spontaneous ideas to tackle problems and write code.
	H	The workshop made me think of an alternative way to solve problems, which is very challenging.
Motivation	I	I am impressed by the achieved result, and escalating my interest in learning IoT and Arduino microcontroller.
	J	The workshop has highly motivated me and I will apply IoT and Arduino microcontroller in my future project.

The survey questionnaire has been provided to all participants for their feedback. The resulting score is determined by using the Likert Scale, which comprises "Strongly Agree, SA = 5", "Agree, A = 4", "Neutral, N = 3", "Disagree, D = 2", and "Strongly Disagree, SD = 1". All the results are compiled into an MS Excel spreadsheet and analyzed by descriptive, *T-test*, and ANOVA analysis.

Descriptive, T-test and ANOVA analysis

Descriptive analysis is a fundamental study of all the collected data. Descriptive analysis performs rational justification for the background study, not in a statistical way. This analysis identifies the significant similarities and differences among all the compared group variables and distributions. At first, all categorical data are compiled and observed by the researcher before commenting on the trends and factors affecting all the compared variables. Frequency and percentage distribution are common approaches used to interpret the categorical survey variables (Alreck & Settle, 1995). Data in categorical distribution can be interpreted clearly via graphical plots, charts, or diagrams. In the circumstances when the variables have too many values in a frequency table, data can be re-processed by reducing the samples during recoding recode them into categories.

The *T-test* is an inferential statistical analysis used to determine whether there is any remarkable divergence between the means of two data sets based on definite features. The *T-test* analyzes the known population means that are mathematically calculated (Crawford & Garthwaite, 2012). Zikmund (2003) described that the *T-test* analyzes the mean scores of selected interval-scaled variables or hypotheses and then tests whether there is a significant difference among the hypotheses. There are two involved hypotheses known as the null hypothesis, H_0 and the alternative hypothesis, H_a. For obtaining the p-value, the t-statistic value, t_{n-1} is to be determined by using $t_{n-1} = (x - \mu)/(s/\sqrt{n})$, where x is the sample mean, μ is the hypothesized mean, s is the sample standard deviation, and n is the sample size. After obtaining the t_{n-1} for that moment, statistical software or the t-distribution table (Statology, 2022) should be referred to for finding the corresponding p-value. For the *p*-value is less than 0.05, the two compared hypotheses are statistically different and therefore reject the H_0. In contrast, two hypotheses are not statistically different and thereby the H_0 is accepted.

ANOVA measures the mean between two or more values of the different contributing groups. The analysis of variance measures the difference between means for more than two data distributions. One-way ANOVA applies one dependent continuous variable but uses more than one independent categorical variable. In the analysis, ANOVA analyses the relation among hypotheses and determines whether there are statistical differences between the populations' means. ANOVA computes the sample variances, F-distribution statistics and eventually to determine the p-value as described by Goos & Meintrup (2016).

Designed Work Activities and Tools

The experimental design for the Arduino microcontroller and IoT tool is shown in Figure 2. All participants are creating a complete set of task step-by-step by employing the given guidelines and source code. The Arduino workshop provided comprehensive guidance on how to create a project for each team and correct all errors in the working instructions. A full set of equipment is also provided to test in real-time operations.

Analysis Results

Descriptive Analysis

The case study accumulated feedback from 91 respondents/participants, who have enrolled for the course Electrical Systems (ELEN 1000) in the year 2024. Among all the participants, 63 were male students, and 28 were female students. This probably reflects that male students prefer to learn knowledge through practical activities, rather than female students that prefers to learn conceptual knowledge, as they feel they can understand well without viewing practical examples. Interestingly, the highest number of 25 participants was from Mechanical Engineering. It is seconded by 20 participants from Electrical and Electronic Engineering, 18 participants from Chemical Engineering, 13 participants from Civil Engineering, 7 participants from Petroleum Engineering, 4 participants from Environment Engineering, and 4 students who were yet to decide on their engineering major. Among all of them, 52 participants or 57.14% were experienced users of the Arduino microcontroller. The demographics of the participants are depicted in Figure 3.

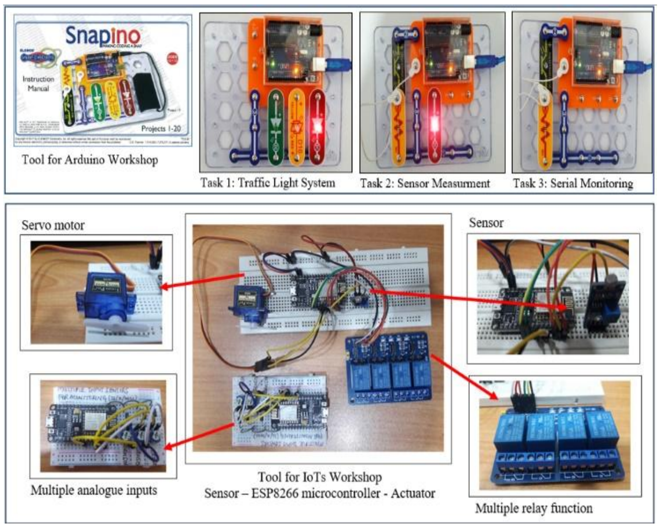

Figure 2. IoTs and Arduino microcontroller workshop activities

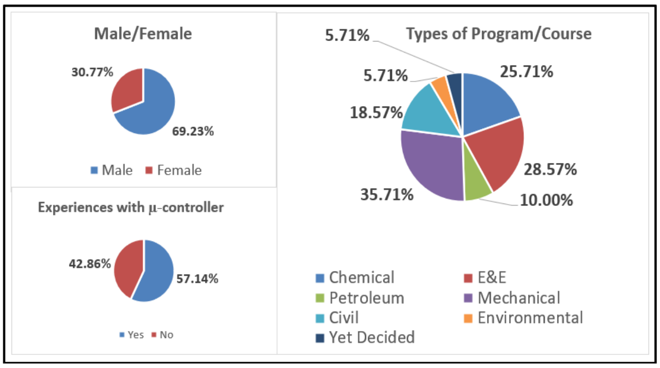

Figure 3. Research population or participants demographics

The score and percentage of every question are tabulated in Table 2. The highest-ranked percentage comes from experiencing co-operation and communication among teammates for completing tasks together (Question F). The feedback reflects that respondents prefer to study with teammates, whereby they have the opportunity to discuss and contribute their ideas in completing the given tasks.

T-test Analysis

There are two hypotheses to be analyzed by using the *T-test* analysis, which is obtainable using Ms. Excel spreadsheet. The *T-test* measures the correlation between two independent variables. All the *T-test* results are illustrated in Table 3.

T-test 1 analyzes the respondents' perceptions of the designed project to improve their conceptual knowledge, which is related to improving their determination to study the IoT and Arduino microcontroller. Question A has gained a mean of 1.61538 and a variance of 0.35042. Question B has gained a lower mean of 1.53846 and a variance of 0.27350. The analysis result of probability, p = 0.08135, which is > 0.05, therefore supports the H0 and supports the statement that the learned knowledge improves determination to study IoT and Arduino microcontroller. *T-test* 2 analyses of respondents' perception of the implemented tasks to visualize the learned knowledge with is helping them to understand the learned knowledge overall. The mean and variance of Question C are 1.5604 and 0.3602, which are greater than those of Question D. Moreover, the *T-test* produces $p = 0.1323$ (> 0.05), so accepting the tested H_0.

T-test 3 researches the correlation of the respondents on the developed confidence levels after solving the designed workshop activities, which has increased their capability to generate a spontaneous idea in dealing with the problems related to IoT and Arduino microcontroller. The mean and variance of Question G are respectively 1.89010 and 0.76557, which are greater than both values of Question E. The *T-test* also shows that $p = 0.02$ (less than 0.05), therefore, two-tested distribution are statistically dissimilar and therefore reject the H_0. *T-test* 4 analyzes respondents' insight on problem-solving process in completing given tasks (Question H) has stimulated their interests to further study IoT and Arduino microcontroller (Question I). The mean and variance of Question H are respectively 1.74725 and 0.67985 and larger than those of Question I, which gain respective values of 1.65934 and 0.53822. The *T-test* result also shows that $p = 0.159996$ (accept the null hypothesis, H_0). That means, the faced challenges of the participants have further escalated their determination to learn IoT and Arduino microcontroller.

Table 2. The respondents feedback analysis spreadsheet

Question Sequence Nu.	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree	
	Freq	*(%)*	*Freq*	*(%)*	*Freq*	*(%)*	*Freq*	*(%)*	*Freq*	*(%)*
A	50	54.95%	37	40.66%	4	4.95%	0	0.00%	0	0.00%
B	48	52.75%	40	43.41%	3	3.85%	0	0.00%	0	0.00%
C	48	52.75%	40	43.41%	3	3.85%	0	0.00%	0	0.00%
D	53	58.24%	31	34.07%	7	7.69%	0	0.00%	0	0.00%
E	37	45.71%	41	45.05%	13	14.84%	0	0.00%	0	0.00%
F	52	64.23%	35	39.01%	3	3.30%	1	0.55%	0	0.00%
G	27	29.67%	35	38.46%	9	9.89%	4	3.85%	0	0.00%
H	28	30.22%	34	37.91%	10	10.99%	2	2.20%	1	0.55%
I	47	51.10%	36	40.11%	7	7.69%	1	1.10%	0	0.00%
J	36	40.11%	40	43.96%	13	13.74%	2	2.20%	0	0.00%

Table 3. *T-test* for selected groups or data distributions

T-test	***T-test* 1**		***T-test* 2**		***T-test* 3**		***T-test* 4**	
	Question A	***Question B***	***Question C***	***Question D***	***Question E***	***Question G***	***Question H***	***Question I***
Mean	1.61538	1.53846	1.56043	1.48351	1.70329	1.89011	1.74725	1.65934
Variance	0.35042	0.27350	0.36019	0.38583	0.47765	0.76557	0.67985	0.53822
Observation	91	91	91	91	91	91	91	91
Pearson Correlation	0.56872		0.42742		0.42321		0.42550	
df	90		90		90		90	
t Stat	1.40752		1.12249		-2.08380		1	
p one-tail	**0.08136**		**0.13231**		**0.02001**		**0.16000**	
t Critical one-tail	1.66196		1.66196		1.66196		1.66196	

Note: p > 0.05 (accept the null hypothesis)

ANOVA Analysis

ANOVA analyses the closed relation among more than two compared independent variables. The *p*-value is used to determine whether the tested hypotheses are statistically significant or vice versa.

In this survey, two ANOVA tests have been conducted in the following sessions, as illustrated in Table 4.

In ANOVA 1, four groups of independent variables include workshop improves understanding (Question B), visualizing the conceptual knowledge (Question C), further enhancing confidence level (Question E), and generating spontaneous ideas (Question H). Among the compared parameters, Question H has gained the largest mean and variance, respectively, as 1.89011 and 0.76557. Whereas Question C has gained the lowest value of mean = 1.4615 and variance = 0.2957. The performed ANOVA analysis shows that *p*-value < 0.05 (*p* = 0.042606) reflects that there is a statistical difference between the four tested group variables; therefore, perception is not accepted.

ANOVA 2 analyses the respondents' perception that the practiced activities are consistent with the learned knowledge (Question B), improves their confidence level (Question E) for trying to solve given tasks (Question H). Both Question B and E gained a similar mean of 1.483516 and a variance of 0.385836. Besides, ANOVA analysis shows that *p*-value =0.368667 (> 0.05) reflects that there is no statistical difference between the three tested group variables; therefore, this perception is accepted.

Discussion

By referring to Table 2, respondents were excited and satisfied with this workshop because of providing them with an invaluable opportunity to practically learn how to develop a workable IoT system by using the microcontroller and IDE programming. 54.95% of respondents strongly agreed, and 40.66% of respondents were highly perceived (Question A) to practice the given tasks when learning conceptual knowledge. This is also reflected in Question D, whereby 52.75% of respondents strongly agreed, and 43.41% agreed, that practical activities immediately allowed them to visualize the learned conceptual knowledge. A respondent from Chemical Engineering commented that "*It was an excellent opportunity to apply what I learned from the lecture into the practical project and understand how applications in daily lives work*."

Secondly, more than 90% of respondents (Question B) perceived that the designed workshop activities are systematic and greatly helped them to understand the principles and knowledge. In the workshop, the designed tasks for instances, such as LED blinking, traffic light, night light system, and data acquisition functions, are fundamental to many engineering applications that involve microcontrollers in the design. An excited respondent from Civil Engineering commented that "*The Arduino project is very suitable for theory teaching to understand the whole electrical knowledge*."

Thirdly, the feedback showed that the workshop escalates students' interest in learning IoT and Arduino microcontroller, as they are excited by the achievements from the workshop. In Question I, 51.10% of respondents strongly agreed, and 40.11% agreed that they were impressed by their abilities and what they were capable of doing while completing the given tasks in the worksheet. A respondent from Electrical & Electronic Engineering: "*This project excites and motivates me to learn more about Arduino Programming*."

Table 4 ANOVA analysis for knowledge, visualizing result, confidence level, spontaneous idea and determination

Groups	ANOVA 1				ANOVA 2		
	Question B	*Question C*	*Question E*	*Question H*	*Question B*	*Question E*	*Question H*
Sum	140	133	155	138	135	135	125
Average	1.53846	1.46154	1.70330	1.89011	1.483516	1.483516	1.373626
Variance	0.27350	0.29573	0.47766	0.76557	0.385836	0.385836	0.325519
Source of Variation	**Between Groups**	**Within Groups**	**Total**		**Between Groups**	**Within Groups**	**Total**
SS	2.95604	128.9451	131.9011		0.73260	98.74725	99.47985
df	3	360	363		2	270	272
MS	0.98535	0.358181			0.36630	0.36573	
F	2.75098				1.001558		
***p*-value**	**0.04261**				**0.368667**		
F-crit	2.62971				3.029218		

Besides, the case study also triggered minor concerns from the respondent's feedback. Primarily, 14.48% of respondents (Question E) were neutral in commenting on enhanced confidence level via step-by-step problem solving for IoT and Arduino microcontroller. This is probably correlated with the 3.85% (Question G) respondents, who perceived that the activities in the workshop were still not adequate to improve their capabilities to produce spontaneous ideas for problem-solving. Perhaps, they have even dealt with the Arduino microcontroller and IoT before, and therefore, felt that the given tasks were not challenging them. Even a respondent from Electrical & Electronic Engineering opined that "*It is better to have the circuit diagram instead of a full image that allows students to think about how to connect the components with Arduino Microcontroller. More complex problems should be given to encourage more creative problem-solving. Ultimately, students can understand better.*"

Amazingly, this workshop has inspired most of the participants to learn further about the microcontroller and IDE programming. More than 80% of the respondents agreed (refer to Question I and Question J) that the workshop has stimulated their interest in further learning about microcontrollers and IoT, and they will consider applying the Arduino microcontroller in their future projects. A respondent from Mechanical Engineering commented that "*It is really helpful for understanding Arduino Microcontroller. I am happy to have a chance to play around with it. In the future, I will recommend it to my friends*." Besides, a student who studied Engineering First Year mentioned that "*This is fun, and I enjoyed it a lot. Please organize it again next year*."

From Table 4, ANOVA 1 analyzes the knowledge learning (Question B) after observing the result (Question C), which improves confidence level (Question E) and generates spontaneous ideas (Question H). Among them, Question N possesses the largest mean and variance values, which is also found from the *T-test* 3 analysis. Probably, few respondents feel the assigned tasks are simple and they lack more comprehensive samples to try when participating in the workshop. Nevertheless, more respondents still feel impressed by their potential and capabilities to complete given tasks in the workshop. Even so, it might be more beneficial to develop an additional worksheet with more complicated tasks to improve the engagement of the experienced participants in the future workshop.

ANOVA 2 analyzed the interrelation of three tested group covers, assigned data to improve knowledge understanding (Question B), improved confidence level (Question E), and tried to solve the given tasks with different approaches (Question H). The probability, $p = 0.368667$ (> 0.5), reflects that the three tested parameters are statistically similar; therefore, it is well to perceive that the workshop has success to enhance knowledge learning and confidence level among participants, that inspire them to strive to complete tasks with different approaches.

Overall, this is a very exciting experience to perform an innovative workshop as participants highly perceive that the workshop helps to boost their learning experience and inspiration in learning microcontroller and IoT. Invaluable findings from the *T-test* 3 and ANOVA 1 are being noted closely, whereby more workshops and comprehensive tasks could be provided for future improvement.

Conclusion

This paper presented an analysis of participants' feedback on the enhanced knowledge, hands-on, confidence level, motivation and spontaneous idea, after completing the project tasks in a designed innovative workshop. As noted, the innovative workshop is a part of the required improvement from the action plan of the student's feedback and concern in studying Arduino microcontroller and IoT. The workshop has enhanced the students' learning experience, particularly in practising the learned knowledge. The targeted population covers multi-disciplinary students who have enrolled in ELEN1000, where they are invited to participate in an Arduino microcontroller and IoT workshop. Fundamentally, the designed activities comprise hardware and software developments for traffic light, night light and data acquisition functions. Participants work in a team to develop project tasks one by one and need to solve the hidden errors to ensure the projects operate as required. Then, participants discussed with the team member how to integrate all the completed tasks to create a more inclusive function. After completing practical activities, participants are required to provide their feedback.

Overall, 91 pieces of feedback were collected from all respondents and were analyzed by using descriptive, *T-test*, and ANOVA analysis. This is favourable to the pronoun that most of the respondents are highly perceiving the innovative workshop that helps to improve their understanding and excitement in learning microcontroller and IDE programming (*T-test* 1) and prefer to learn practical activities concurrently with the conceptual knowledge because of helping them to visualize the learned knowledge (*T-test* 2). Perhaps due to the limited time for the workshop, respondents still feel their confidence level is not adequate for accessing spontaneous ideas dealing with future problems. In addition, the feedback is probably given by an excited respondent who is experienced in dealing with Arduino microcontrollers and IDE programming (*T-test* 3). Most of the respondents highly perceived that the challenges they faced in proceeding project tasks have inspired their interest to further learn microcontroller and IDE programming (*T-test* 4). The analysis is also extended by using the ANOVA method. ANOVA Test 1 found that the innovative workshop makes most of the respondents amazed at their capabilities to complete the given tasks during the workshop. However, the finding shows concern about the capability to generate spontaneous ideas. Last but not least, ANOVA Test 2 found that practical activities in the workshop are aligned with the conceptual knowledge, have improved participants' confidence levels and inspiration to thrive on tackling the assigned problem task with different approaches in the workshop.

In conclusion, the organized, innovative workshops were conducted successfully. Both the positive and negative feedback are well noted and followed up with improvements in teaching and innovative workshops in future semesters. Satisfaction and motivations of instructors are credited to the appreciation and encouragement words from all respondents, who have strongly recommended that this innovative workshop should continue for future semesters.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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