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Potential of Problem-Solving Flipped Classroom Instruction in teaching Internet of Things (IoT) at Community Colleges: A Needs Analysis

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Umawathy Techanamurthy[1,*], Zanariah Ahmad[2], Noorfadhilah Kahar[3], Fadhlina Ahmad[4], Ana Rohana Pataniah Salahuddin[3]

[1] Instructional and Digital Learning Division, Department of Polytechnic and Community Colleges, Putrajaya, Malaysia
[2] Department of Education, Faculty of Technical and Vocational Education, University Tun Hussein Onn Malaysia, Johor, Malaysia
[3] Academic Unit, Hulu Selangor Community College, Selangor, Malaysia
[4] Academic Unit, Hulu Langat Community College, Selangor, Malaysia

ABSTRACT

Flipped Classroom enables instructors to spend more time for hands-on problem-solving instruction compared to the traditional pedagogical model which involves lectures. The purpose of this study is to determine the need for a problem-solving flipped classroom module to be designed for the STM3023: Internet of Things (IoT) subject offered at the Certificate level at Malaysian Community Colleges. A structured interview was conducted with 16 lecturers from 14 Community Colleges offering the subject to obtain their views on current teaching practices along with the challenges faced in the teaching and learning of IoT to entry level students. Participants were also asked about their readiness towards the flipped classroom following an orientation session on Flipped Classroom approach. The findings showed that lecturers mostly used traditional pedagogical models in the TVET settings such as lectures. Students usually followed instructions and merely replicate the hands-on tasks as demonstrated by their lecturers in class. It was also found that students were struggling with the subject due to their lack of competency in programming and grasping electrical and electronics concepts. Students were also found to be weak in mathematics and reasoning skills, thus making it a challenge to teach IoT to them. Therefore, a myriad of media, materials and application of real-world concepts may be required to aid lecturers to improve students' achievement in the subject. The flipped classroom approach for teaching which gives more time for hands-on problem-solving instruction may be appropriate to support lecturers to overcome the challenges in teaching IoT.

Keywords:
Internet of Things; Flipped Classroom; problem solving; needs analysis; reasoning

1. Introduction

Internet of Things (IoT), being the most emerging area of computing, is an umbrella term that is used to describe "smart devices" that consist of everyday objects which are enclosed with small,

* *Corresponding author.*
E-mail address: uma_leogal@yahoo.com

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uniquely identifiable, internet enabled hardware components. IoT plays a significant role in creating new ways of performing tasks, automating or communicating. In Malaysia, the Ministry of Science, Technology and Innovation (MOSTI) and MIMOS have published the National IoT Strategic Roadmap [1]. One of the goals of the National IoT Strategic Roadmap is to make the country as the Regional Development Hub for IoT; with the establishment of an integrated centre for IoT solutions, equipped with supporting services and facilities such as interoperability testing and development of IoT products and services. This will eventually enable Malaysia to be positioned as the preferred location for IoT outsourcing services for the Malaysian industry and the world at large.

To be in line with the needs of the government, the Department of Polytechnic and Community Colleges has introduced STM3023: Internet of Things as a new course in August 2017 to be taken by students in their third semester of Certificate in Information Technology programme (*Sijil Teknologi Maklumat*). The course contents cover only the fundamentals of IoT, interfacing sensors to the internet using Python programming for Raspberry Pi and using low-cost programmable microcontroller Arduino boards. Students will be assessed through projects, that require them to program a board to read digital and analog inputs, for example, from a light sensor, and control a number of outputs, for example, activating on/off a LED which includes some basics of electric and electronics. Thus, the teaching and learning of IoT may require a background in subjects such as electricity, magnetism, electrical circuits, electric motors, power systems, control systems, sensors, electro-optics, communication systems, analog electronics, digital electronics, microprocessors, digital controllers, programmable devices, and programming [2]. The use of the Arduino and Raspberry Pi platform requires familiarity with Java syntax and semantics, and the ability to debug Java compilation errors (e.g., misspelled variables or misplaced semicolons) for success. These challenges presented barriers to entry for individuals not versed in coding. Since the advent of IoT enables developers to solve day-to-day problems, students need to be trained to be innovative and come up with different ways of solving problems.

We are moving toward economies of knowledge. In these economies, access to new innovations and ways of solving problems will differentiate individuals competing globally [3]. Tools that provide increased abstraction for solving problems will offer more advantages to individuals than traditional approaches. This requires a reform in the traditional pedagogical approach so that instructors can pay attention to creating a balance between theoretical knowledge and applied knowledge so that students can develop their problem-solving skills. Technology can be integrated into TVET via a flexible and blended approach to plan the use of in-classroom time and out-of-classroom time properly[4]. The flipped classroom approach is a blended learning strategy enabling the planning of the use of in-classroom time and out-of-classroom time properly. The out-of-classroom time can be conducted online for students to come prepared with knowledge and comprehension of subject matter, whereas the main face-to-face learning activity during in-classroom time can be designed around tasks or problems. This means, scheduled class time can be utilized for more meaningful learning to occur by conducting problem-solving activities for deeper understanding of subject matter [5,6].

2. Methodology

A structured interview was conducted during a face-to-face workshop to gain insight on the current teaching practice and particularly to assess the need for a problem-solving flipped classroom. The researchers facilitated the session and the respondents answered the survey online. Around 16 lecturers who are teaching the STM3023: Internet of Things subject from 14 Community Colleges across Malaysia were present at the session. See Table 1. The structured interview questions were divided into five sections and adopted both open-ended and closed-ended questions. The two research questions are: (i) What are the current teaching practices of the IoT instructors of Community Colleges? and (ii) What is the flipped classroom design preference of the IoT instructors of Community Colleges? Section A consisted of general questions to identify the background of respondents. Section B aimed to find out the views and opinions from the respondents on current teaching practices, which allows them to share on what are the instructional strategies, activities, resources, materials and assessment currently being used. Section C aimed to get insight from respondents on the current teaching practices in inculcating problem-solving skills among students in terms of instructional strategies, activities, resources, material and assessment used. Section D consists of several questions intended for respondents to express on the perceived barriers and challenges faced in developing students' problem-solving skills. Lastly, Section E is constructed to determine their flipped classroom readiness if it were to be implemented.

3. Results

3.1 Profile of instructors

The 16 respondents were those currently teaching the STM3023: Internet of Things subject from 14 Community College across Malaysia. The diversity of the respondents in terms of their background, years of experience and locations enabled this study to accumulate more quality data. See Table 1.

It was found that 75% (n=12) of the respondents were female lecturers. Majority of the respondents; 87.5% (n=14) came from the non-engineering background i.e. Information Technology, Computer Science, Computer Networking and Software Engineering cluster compared to the engineering background. Only five respondents (31.25%) had industrial experience in the field, whereas the rest did not have any. In looking at respondents' teaching experience, a majority of the lecturers, 87.5% (n=14) have been teaching for more than five years.

3.2 Instructors' Current Teaching Practice

This section discusses the findings obtained to answer the first research question which is as follows: "What are the current teaching practices of the IoT instructors of Community Colleges?". Among the areas investigated were (i) investigators' current teaching practices, (ii) instructors' current teaching practices of problem-solving skills among students and (iii) the challenges instructors face in integrating problem-solving skills into their current teaching practices.

The three main themes emerging from the qualitative data collected are as follows: the use of the traditional TVET pedagogical model with blended learning, lack of problem-solving instruction, and the challenges faced in developing students' problem-solving skills due to students lack of problem-solving skills and instructors lack of knowledge in the subject matter.

3.2.1 Use of traditional TVET pedagogical model with blended learning

All the respondents mentioned that the Culinary Arts programme taught in Community Colleges consists of both the theoretical component and the hands-on practicum which is prevalent in TVET settings. The current teaching arrangement for IoT is mostly maintained at five hours a week with an allocation of two hours on theory and remaining three hours on hands-on practicum. Lessons are conducted in an instructor-centred manner (lectures and demonstration) coupled with blended-learning approach. During theory session, lecture content is delivered through PowerPoint presentations, sharing of online web resources and distribution of lecture notes. The notes are distributed to students by both means, hard-copy and soft-copy using various free-to-use learning management systems (LMS) such as *Edmodo*, *Schoology*, *Google Classroom* and mobile messaging app such as *Telegram*. Students are also given the task to prepare presentation slides on topics to present with the class. Lecturers will provide feedback when needed. To assess knowledge and understanding, lecturers conduct quizzes, assignments and exercises. Applications such as *Kahoot* and *Quizizz* are also used by the lecturer to engage students.

Table 1
Profile of the Respondents

Pseudonym	Sex (M/F)	Background	Years of teaching experience	Years of industrial experience
A1	M	Information Technology	5 – 10 years	1-5 years
A2	F	Computer Science	> 15 years	None
A3	F	Software Engineering	5 – 10 years	None
A4	F	Software Engineering	5 – 10 years	None
A5	F	Software Engineering	1 – 5 years	1 – 5 years
A6	M	Computer Science	10 – 15 years	10 – 15 years
A7	F	Information Technology	10 – 15 years	10 – 15 years
A8	F	Information Technology	> 15 years	None
A9	F	Electrical Engineering	1 – 5 years	None
A10	F	Computer Networking	10 – 15 years	None
A11	F	Electrical Engineering	> 15 years	None
A12	F	Information Technology	5 – 10 years	None
A13	F	Information Technology	5 – 10 years	None
A14	F	Information Technology	5 – 10 years	1 – 5 years
A15	M	Information Technology	10 – 15 years	None
A16	M	Information Technology	10 – 15 years	None

Practical sessions on the other hand, consists of live demonstration step-by-step practical tasks by lecturers for students to replicate step by step. This approach is typical in a traditional TVET setting. Students usually worked in groups to assemble components, and work individually to program and debug the errors. Students use YouTube videos as learning resources and completed lab sheets given by the lecturers. Rubrics are used to assess the hands-on practical tasks. After lessons are over, lecturers will summarise the overall topic learnt for the day, have a short reflective session and provide brief explanation on the following lesson. Students usually work on given projects as homework if they do not finish it during class. Thus, instructor's current teaching practices consists of traditional lectures, blended learning and hands-on sessions which are limited to demonstration and replication of hands-on techniques in the lab.

3.2.2 Lack of instructional materials and guidance for instruction

When asked if lecturers inculcate problem-solving skills among students through instructional strategies or activities used in their lesson, all lecturers unanimously highlighted that they did not use problem-solving instruction to inculcate problem-solving skill among the students. Instead, students usually follow the instructions step-by-step and replicate what are taught by the lecturer in class. Students are also given homework to complete which are similar to what they have learned in class. 75% (n=12) lecturers claim that they do not seem to have the resources to teach for problem-solving activities hence, they refrain from giving students real-world problems to solve. They also claim they do not have sufficient resources to conduct problem-solving instruction. The other 25% (n=4) provide real-world problems to solve in class such as the automated lighting system and automated plant watering system which are based on past experiences and observations on real-world problems. Coincidentally, they also happen to be lecturers with the engineering background. Despite the lack of teaching using real-world problems, almost half of the lecturers are able to provide example of real-world workplace problems. Examples that are given are as following: solar panel for energy saving, automated gate, smart lighting, smart air-conditioner and automated plant watering system and smart CCTV.

3.2.3 Challenges faced in developing students' problem-solving skills

The final theme emerging from the interview with the lecturers was the perceived barriers that instructors faced in developing their students' problem-solving skills. The sub-themes gathered were both instructors and students' low-level understanding of electric and electronic concepts, low-level of programming and logical thinking skills and students "doing without learning".

3.2.3.1 Low-level understanding of electrical and electronic concepts

When asked whether their students are able to solve real-world workplace problems like the ones suggested, there were mixed reviews coming from the lecturers with regards to student capabilities to solve real-world problems. Only 43.75% (n=7) said their students will be able to solve the real-world workplace problems as mentioned, provided that the lecturers are equipped with adequate resources, training skills and high level of competency to provide the best learning environment for the students. One respondent felt that students on the other hand should be independent and must have interest to explore the ways and technique in depth. The other half claim that they do not think the students have the capability to do so, because of low level of understanding of the IoT and programming concepts among students. Nearly all lecturers mentioned that they are lacking in knowledge, skills, training, experience and resources to teach the subject. The main reason cited is teaching IoT subject without having any background in electronics. This prevents majority of the lecturers from developing students' problem-solving skills and teaching the subject effectively. Evidence noted by instructors are as follows:

> *"The IoT subject involves electric and electronic components and schematic diagrams. Students find it difficult to understand the electric and electronic concepts as the lecturer themselves find it difficult to explain and make students to understand the concepts"* (A2)

> *"Students struggle most with the motor and electronic parts as they do not have basic knowledge and understanding on those parts… most lecturers do not have basics in electronics… most lecturers are from the Information Technology background"* (A3)

3.2.2.3 Low level of programming and logical thinking skills

Other than that, instructors highlighted that students seem to lack interest in the subject, especially due to the programming component, due to their lack of mathematical and logical thinking abilities.

> *"… students are poor in Mathematics"*(A3)
> *"Some students struggle in assembling components and coding part because some of them are weak in mathematics and logical thinking"* (A4)
> *"…almost all students are weak in mathematics which makes it difficult for them to write the algorithm for their projects*" (A15)

Thus, students also seem to lack interest in the subject ask they find it difficult to grasp the concepts easily and lose confidence. Furthermore, instructors also lamented that most students do not seem to come prepared for class.

"Notes have been given beforehand, but students are unable to give even simple answers before the lessons begin. (A8)

3.2.2.4 Students "doing without learning"

Instructors also shared that that students are replicating what they have taught without really learning. For instance, students are not able to integrate the knowledge when asked to create an innovative project of their own. It appears that the teaching method employed is similar to the traditional TVET pedagogical model which follows the "instructor briefing-instructor demonstrate-student replicates-instructor debriefing" flow of instruction. This procedure is also illustrated by the instructors.

> *"…student just replicate what lecturer taught"* (A5)
> *"...students only solve the problems demonstrated by lecturers only…"* (A3)

A few other lecturers added that they do not teach students to problem-solve as students replicate what has been demonstrated. The projects also usually are similar to the demonstrated tasks and students may not be able to work independently.

> *"Yes, we give them similar problem that we assist them before and they need to solve by their own"* (A7)
> *Students only can solve problems after receiving full assistance from the lecturer".* (A8)

3.2.5 Instructors lack of training to teach IoT

Another challenge perceived by instructors were the lack of training to teach the subject. When lecturers themselves seem to be unprepared, they seem to struggle to facilitate lessons.

> *Lecturers were not given any training before teaching the IoT subject so lecturers need to explore the subject themselves (A4)*
> *… The lecturers themselves do not have enough exposure to this subject in detail… "(A8)*

Thus, majority lecturers suggested more content to be added to the existing curriculum to enable both students and lecturers to be grasp the subject matter better, especially on fundamental electric and electronic concepts:

> *"Supposedly, students should be taught how to draw a schematic diagram first, but the lecturers are not from the electric and electronic background. The syllabus should include drawing electronic circuit diagrams so that both lecturers and students gain better understanding on how to sketch the diagram before the practical tasks."* (A4)
> *"…electronic circuit diagram, electronic component… because even some of the lecturers are having the same problem (grasping those concepts just like students)"* (A6)
> *Thus,*

The findings from the interview provided themes that are summarised in Figure 1. Based on Figure 1 several recommendations will be made to the design of the module. These will be then used as guidelines for designing and developing a new module for IoT.

- *Use of traditional TVET pedagogical model with blended learning*
    - *Instructor centered lectures*
    - *Demonstration-replication step by step*
    - *Blended learning using PowerPoint slides, web resources on LMS*
- *Lack of instructional materials and guidance for instruction*
    - *Do not inculcate problem-solving skills, students' homework similar to the tasks given in class*
- *Challenges*
    - *Low-level understanding of electric and electronic concepts*
    - *Low-level of programming and logical thinking skills*
    - *Students "doing without learning"*
    - *Lecturers lack training to teach the IoT subject*

Fig. 1. Summary of themes for current teaching practices

Since IoT is a new subject in the CC curriculum, it is important to highlight some reforms required in teaching this subject to reflect both the technological changes and objectives of education in the twenty-first century. The new technologies may become a cover-up or trap of superficial learning; students still need to acquire some basic knowledge and skills before dealing with the development of advanced technological systems.

Firstly, instead of using the traditional pedagogical model which consists of blended learning and traditional hands-on practicum that consists of demonstration-replication, there is a need to shift to include active learning strategies to ensure students grasp fundamental concepts. It is crucial to get students to actively participate in the learning process especially on concepts which may be too abstract to students such as electronic and electrical circuits or programming. In this study, it was found that not only students were having difficulty understanding the concepts of IoT. It seems that this issue poses major challenge to lecturers especially those from the non-engineering background who are the majority. They seem to lack training and skills that allow them to teach electronic concepts adequately. It turns out that without electronics background, lecturers are struggling to teach both the content and hands-on tasks. Thus, they need to be trained on the electronic and electrical circuits concepts so that they can have better content comprehension and be able to connect real-world applications of theoretical concepts which may seem to abstract.

Programming is a skill that helps people learn how to think systematically. By developing computational thinking, people can break down complex problems into manageable parts, look for similarities among and within problems and identify different recommendations step by step. For people who do not have technical knowledge, computational thinking may seem too abstract and programming may seem too technical. The use of the Arduino and Raspberry Pi platform requires familiarity with Java syntax and semantics, and the ability to debug Java compilation errors (e.g., misspelled variables or misplaced semicolons) for success. These challenges presented barriers to entry for individuals not versed in coding. Nevertheless, block programming is also introduced using the Scratch app in order to *h*ide the complexity of data structures behind blocks so that students can spend more time designing apps that perform data collection and analysis, or integrate with a range of sensors and actuators interacting with external environments. This allows for a top-down, goal-based decomposition of the problem rather than a bottom-up approach.

3.3 Instructors' Flipped Classroom Design Preference

This section discusses the findings obtained to answer the second research question which is as follows: "What is the flipped classroom design preference of the IoT instructors of Community Colleges?". An awareness of the FC approach is a pre-requisite for successful FC [7]. From the 16 respondents surveyed, 11 (68.8%) were unaware of Flipped Classroom. More than half of them strongly agreed that face-to-face instruction should constitute between 50-80% of the course delivery, while only two of the respondents were of the opinion that face-to-face should make up only 40% of the course delivery. Interestingly all lecturers unanimously agreed that they would adapt the flipped classroom approach because the method enables students to be more prepared for the classroom.

Table 2
Results of Respondents' Level of Readiness in FC

FC Readiness	*n*	%
Awareness of Flipped Classroom		
Yes	5	31.2
No	11	68.8
Face-to-face (f2f) versus online		
f2f 90%: Online 10%	-	-
f2f 80%: Online 20%	8	50
f2f 70%: Online 30%	3	18.8
f2f 60%: Online 40%	-	-
f2f 50%: Online 50%	3	18.8
f2f 40%: Online 60%	2	12.5
f2f 30%: Online 70%	-	-
f2f 20%: Online 80%	-	-
f2f 10%: Online 90%	-	-
Content Format		
Text only (PDF)	2	12.5%
PowerPoint Slides	11	68.8%
Audio Podcast	-	0%
Video	14	87.5%
PowerPoint slides with audio explanation	7	43.8%
PowerPoint slides with video explanation	12	75%
Animated Videos	13	81.3%
Animated Text	3	18.8%
Text (PDF) with audio explanation	1	6.3
Text (PDF) with video explanation	3	31.3
Interactive media	3	6.3%

In addition, the approach also allows students to explore more ideas on real world problems that can not only assist them but also further improve their problem-solving skills. Finally, when asked which topic would be their flipped lesson, most lectures ranked the Introduction to IoT topic, followed by the topics on motor, sensors, circuit diagram and programming. This seems to indicate that the respondents are ready to implement their lessons using the Problem-Solving Flipped Classroom approach. The lessons in the module should be designed with an emphasis on face-to-face session to ensure better success. As for the respondents' preferred content format for online materials, statistics show that their highest preference was for materials to be delivered using videos (87.5%), followed by the use of animated videos (81.3%) and *PowerPoint* with video explanations (75%). (See Table 2).

About FC readiness, the majority of respondents were unaware of the FC approach. However, quantitative data revealed that face-to-face instruction should account for between 50% and 80% of course delivery. This tells us that there is a need to use class time to include more hands-on learning experience so that students actively participate in the learning process. This means that there is a need to design a model of instruction to shift teaching practice from traditional lecture to student-centred approaches. Moreover, the need to enhance content comprehension and knowledge retention can be achieved using active learning strategies.

4. Conclusions

The needs analysis phase has provided findings about the teaching of IoT at the Community College setting and the background of both instructors and students. The above findings indicate that there is a pressing need to improve students' level of problem-solving skill and instructors' need guidance on implementing problem solving instruction to facilitate the flipped classroom approach in an IoT classroom. Moreover, when designing the content areas for the flipped module, basic electric and electronic concepts must be added to enable users of the module to grasp the concepts of electronic circuit diagrams and motor components. Other important areas to emphasise are the to include activities on key coding topics to help students better understand projects. As argued by [8], these findings are especially useful when designing technology mediated instruction that is socially and culturally relevant.

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