FROM LAB-BASED TO HOME-BASED: APPLICATION OF BLENDED LEARNING

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ABSTRACT

Year 2 students from the Diploma in Electronic Systems course in the School of Engineering, Nanyang Polytechnic had to complete a project as part of the Electronic Communication module through blended learning. The project development involved circuit connections, coding and testing to demonstrate the wireless communication between two Arduino boards to solve real-life problems. With all classes converted to home-based learning during the pandemic, this poses a challenge for lecturers to quickly convert hands-on engineering project with hardware and software development online while ensuring that learning outcomes were not compromised. This paper will explain how the learning outcomes were achieved via Tinkercad during the home-based learning period. The paper will also cover the various means allowing learners to integrate both hardware and software to implement a solution for the identified problem statement. Some of the challenges faced along the implementation will also be shared, together with measures put in place to mitigate the challenges moving forward.

KEYWORDS

Home-based learning, Blended learning, Project development, Active learning, Standards: 8

Note – In the context of Nanyang Polytechnic, the term ‘course’ refers to a ‘program’ while the term ‘module’ refers to a ‘course’. For example, *Diploma in Electronic Systems* is a course; *Electronic Communication* is a module.

INTRODUCTION

The learners from the Diploma in Electronic Systems course study the Electronic Communication module in their year 2. The module is designed based on Bigg’s model of Constructive Alignment; where the intended learning outcomes, learning activities and assessments were carefully planned, to optimize learning (Biggs, 2011). The module aims to provide learners with the knowledge of the basic elements of a communication system and

how information signals may be transmitted using modulated carrier signals for analog and digital systems.
In order to achieve the learning outcomes, the learners undergo a total of 90 hours in 15 weeks of lecture, tutorial and practical sessions in one semester, with the final aim that learners will develop an understanding of how electronic communication technology could be adopted in modern society through projects. To achieve this final aim, one of the learning activities in this module is the project phase.

Table 1 shows the module's instructional learning outcomes (ILO) for the project portion, with 18 hours for practical and 12 hours for e-learning. The first ILO is rated level 6 for cognitive and level 2 for psychomotor based on Bloom's taxonomy (Bloom et al., 1956), which can be translated to creating and manipulation respectively, where learners are expected to build a system solution with hardware connections and code development for wireless communication. Similarly, based on Bloom's taxonomy, the second ILO is rated level 3 for cognitive, which can be translated to applying acquired knowledge to deliver a project presentation and demonstration.

Table 1. An Excerpt of Module Instructional Outcomes

Topic	Instructional Learning Outcomes & Hours				Bloom's Taxonomy Domain level		
	L	T	P	E			
	At the end of this topic, students will be able to				Cognitive	Psycho-motor	Affective
Application Project	0	0	18	12			
Application Project	1. Build a system solution using digital RF transmitter and receiver. 2. Participate in a project presentation and demonstration.				6 3	2	

(L – Lecture T- Tutorial P – Practical E – e-Learning)

This project component is also mapped to the following module learning outcomes:

At the end of this module, learners will be able to:

- analyse analog and digital communication systems by graphical illustrations and applying the concepts in the building of the systems.
- demonstrate the electronic communication concepts through developing and implementing solutions for real-life applications.

As such, the project requires the learners to perform hardware connections and Arduino code development. Learning packages using Storyline were developed to guide the learners, which made it easier for learners to quickly find the information that they need and to implement in bite sizes. After picking up essential skills, learners will propose and implement solutions for real-life problems. We want our learners to embrace Active Learning (CDIO Standard 8),where they will be engaged with self-directed learning to research, identify problems and implement

solutions. Hence, learners are free to propose their projects and the complexity of the projects will then be decided by them.
This project forms 20% of the assessment component for this module. Learners are assessed based on their attendance, project features and functionality, contribution, project documentation and question-and-answer. Figure 1 shows the delivery of this project in a typical semester.

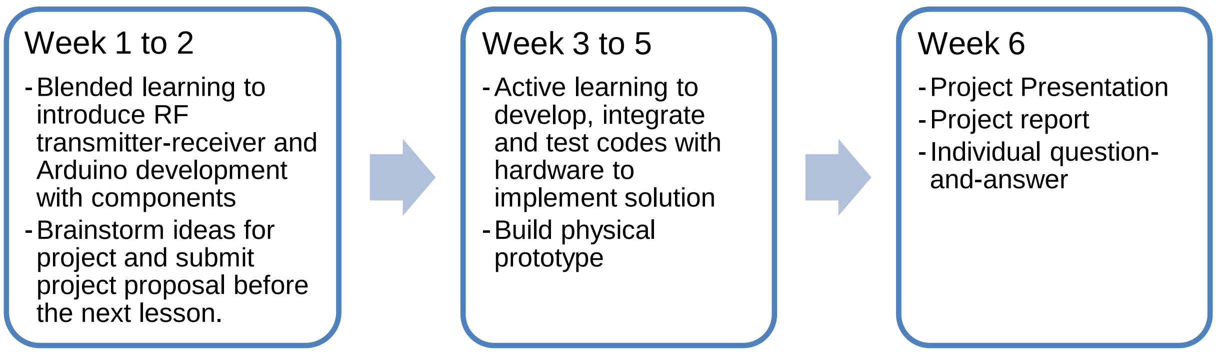

Figure 1. Project Delivery

In this paper, the focus will be on the project phase of the module, explaining how the transition from lab-based to home-based implementation was achieved while ensuring that the learning outcomes were not compromised.

PEDAGOGY

Active learning is a learning method which encourages the learners to be actively or experientially involved in the learning process, and to achieve this, different levels of active learning can be applied, depending on learner involvement (Bonwell et al., 1991). For active learning to take place, learners must be engaged when solving problems, through discussions with facilitators and peers, seeking out knowledge on their own and having a sustained inquiry mindset.

The learning methods discussed can be part of learning activities, that can be used to achieve the desired learning outcomes. In addition, with the aid of technology in education, blended learning approach towards active learning in lessons have been trending and showing improvement in achieving learning goals as well (Arianne et al., 2008, Prince et al.,Chadia et al., 2019).

PROJECT DESIGN IN THE MODULE

This project involved RF communication between a transmitter Arduino board with sensors and a receiver Arduino board with actuators. Over the course of 6 weeks, learners went from picking up the basic skills in RF communication and Arduino development, wiring sensors and actuators, programming the Arduino boards to read sensor readings, send and receive data and control actuators, to finally implementing their own solution to a real-life problem.

In the following sub-segments, the usual face-to-face lab-based implementation of this project will be discussed first, followed by the home-based implementation.

Face-to-face Lab-Based Implementation

In the first 2 weeks of blended learning, learners went through 4 e-learning packages which covered the theory of RF communication, introduction to Arduino development, circuit connections for transmitter and receiver boards, and sample codes as shown in Figure 2. A challenge was given at the end of each session for them to enhance their codes to meet a certain requirement. They were able to connect sensors such as temperature sensor and light intensity sensor to the transmitter board, read the sensor readings and send data to the receiver board using the VirtualWire Arduino library. At the receiver board, different actions will be performed, depending on the received data to control actuators such as turning on a light emitting diode and rotating a servo motor.

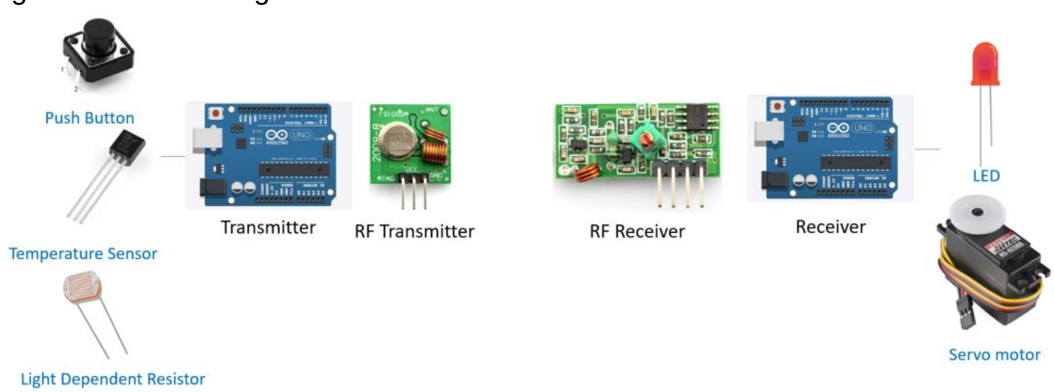

Figure 2. System Overview of the 4 Guided Labs

Armed with the newly acquired knowledge, learners moved on to the next phase of brainstorming to define a problem statement and possible solutions. They worked in pairs and were encouraged to post their ideas in Padlet for others to comment, discuss and improve their ideas. They will then submit a project proposal and the lecturer will give more inputs and suggestions. Project ideas range from smart streetlights, healthcare, doghouse, home security and automation, garden, temperature scanning and access, cafe, carpark to smart trashcan. Please refer to Table 2 for some samples of the project proposals.

Table 2. Project Proposal Submission Samples

Title	Description
Smart Garden	People worry about watering the plants when they are away for long trips. A smart garden with sensors will help to water the plants when soil is dry and turn on the lights when it is dark. This ensures that plants can have enough water and light to grow well.
	Sensors: Soil moisture senor, LDR
	Actuators: Water pump, LED

Smart Study Corner	Outdoor study areas are either equipped with a manually activated fan or air-conditioned. Sometimes, people may forget to turn off before leaving the area which leads to a waste of electricity. A smart study corner with temperature sensor and motion sensor helps to detect people's presence and to turn on the fan when someone is at the area and it is hot.
	Sensors: Temperature sensor, motion sensor
	Actuators: Fan, LED
Remote Patient Monitoring System	In healthcare institutions, it is critical to monitor the vital signs of a patient and nurses must be alert quickly when there is abnormality. This remote patient monitoring system uses heartrate sensor and GSR sensor to monitor the patient. Data will be displayed on the LCD at the nurses' station. Alerts like buzzer and led will be activated, when an abnormality such as fast heart rate or abnormal GSR value occurs.
	Sensors: Heartrate sensor, galvanic skin response sensor
	Actuators: LCD, LED, buzzer

(LED – light emitting diode, LCD – liquid crystal display, LDR – light dependent resistor)

Learners will then spend the next 4 weeks in active learning, to do their own self-directed research in integrating the new sensors and actuators to their transmitter-receiver boards and trouble-shooting their codes and connections, to implement their solutions. Online materials / tutorials were provided to guide them in the correct direction. They will also build a prototype to house all the hardware and to showcase the features.

Learners will be assessed through a sales pitch, where they will present the problem statement and demonstrate the features of their solutions. A project report will also be required to document the project development. The lecturer will conduct an individual question-and-answer session to assess their level of understanding in code development.

Sample Project - Lab-Based Implementation

Figure 3. Learner's Project Submission with Prototype

Figure 3 shows one of the project submissions on smart garden. The learners used soil moisture sensor to monitor the soil moisture level and activate a water pump to water the plants. In addition, a light sensor is used to detect ambient light which will turn on the LEDs if it is dark.

Home-Based Implementation

When Singapore imposed the circuit breaker measures in April 2020 in response to the COVID-19 pandemic, schools were closed, and all lessons were conducted via home-based learning. This poses a challenge for lecturers to quickly convert hands-on engineering project online while ensuring that learning outcomes were not compromised.

Some considerations to take note while researching for a suitable platform include:

- No hardware is given to learners
- Due to the short timeframe of 2 weeks before semester starts, chosen platform should preferably be free-ware and require easy installation by learners or completely online.
- Chosen platform must support multiple Arduino boards in one project, provide a good selection of sensors and actuators, support breadboard connection & code development and simulate results with serial monitor.

A scan of available Arduino simulators reveals that some requires actual Arduino board to upload the codes, some do not support breadboard connections and some only support one Arduino board in one project. After much research and deliberation, Tinkercad platform was chosen for this purpose.

Tinkercad library provides components such as Arduino board, sensors and actuators. Learners were able to go through the entire development process, from placing components on the breadboard, wiring them to the Arduino board, writing codes, running simulation with the ability to adjust sensor readings and printing debugging messages in the serial monitor. Furthermore, lecturers could create a virtual classroom for learners, where all their project development could be viewed and executed by the lecturer. This served as an important channel for the lecturer to view the learners' progress and to give feedback to them.

However, the RF transmitter and receiver modules are not available in the Tinkercad library for wireless communication. For this home-based implementation, the wireless communication is replaced by a pair of wired serial communication between the two Arduino boards and SoftwareSerial Arduino library is used instead of the VirtualWire Arduino library.

Storyline packages were developed with screen recording to demonstrate the features of Tinkercad, Arduino development, circuit connections for transmitter and receiver boards and sample codes. Similar to the lab-based implementation, learners spent the first 2 weeks doing 4 guided lab exercises to get themselves familiar with the Tinkercad platform, building both transmitter and receiver circuits, writing codes and sending or receiving data. In addition, the wireless communication is demonstrated in a video with the actual hardware and the slight differences in codes are highlighted so that learners can appreciate how each project can be easily converted from wired connections to wireless.

During the following 4 weeks, learners brainstormed to identify a problem statement and implement their solutions. The difference from the lab-based learning is that they are limited by the available sensors and actuators in Tinkercad as shown in Figure 4.

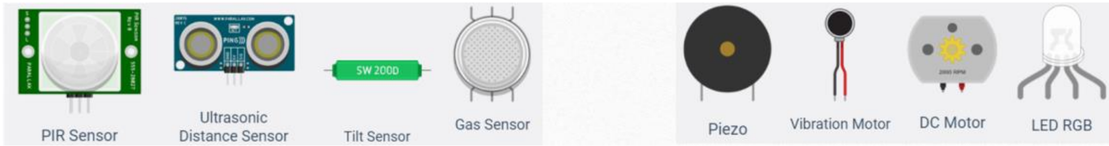

Figure 4. List of Common Sensors and Actuators in Tinkercad

Throughout the home-based learning period, consultations were available through Zoom video conferencing tool. With the virtual classroom, lecturers have direct access to all the projects to view circuit connections and codes, give comments, run simulation and identify errors if learners need help.

Sample Project - Home-Based Implementation

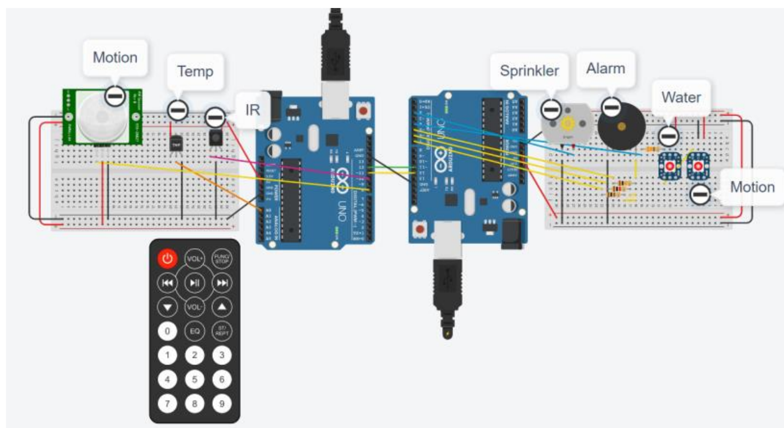

Figure 5. Learner's Project Submission using Tinkercad

Figure 5 shows one of the learner's project submission on smart garden with security alert. The learner used temperature sensor to monitor the temperature and activate a sprinkler (denoted by a DC motor) to water the plants. In addition, a passive infrared sensor is used to detect motion which will trigger an alarm if intruder is detected. This system also comes with an infrared remote controller for the user to remotely arm or disarm the security alert or to control the water sprinkler. Ideally, the learner should have used a soil moisture sensor to detect the moisture in soil and a water pump in place of the DC motor. Due to the availability of the components, an equivalent one was used as a replacement. In terms of the complexity of codes, both are equivalent as they are analog sensors and digital actuators.

Comparison on the Approaches

The comparison between the two approaches can be summarized in Table 3 below.

Table 3. Learning Activities during Lab-based and Home-based Implementations

Week	Activities during Lab-Based implementation	Activities during Home-Based implementation
Week 1 to 2	- Blended learning to cover the following topics:	- Blended learning to cover the following topics:

	• Introduction to ***RF transmitter-receiver*** and Arduino development ***using hardware and components*** • Wireless switch • Temperature sensor and actuator • Light sensor and actuator - Brainstorm ideas for project and submit project proposal before the next lesson.	• Introduction to ***serial communication*** and Arduino development ***using Tinkercad*** • Wireless switch • Temperature sensor and actuator • Light sensor and actuator - Brainstorm ideas for project and submit project proposal before the next lesson.
Week 3 to 5	- Active learning to develop, integrate and test codes *with hardware* to implement solution - Build ***physical*** prototype	- Active learning to develop, integrate and test codes with ***software simulator*** to implement solution
Week 6	- Project Presentation - Project report - Individual question-and-answer	- Project Presentation - Project report - Individual question-and-answer

RESULTS AND DISCUSSION

A total of 17 learners studied this module and completed the project when this study was conducted, using the home-based implementation. A survey was conducted to gather feedback on using Tinkercad platform in terms of achieving the instructional learning outcomes. 14 out of 17 learners responded, and the results is shown in Table 4.

Table 4. Survey Results

S/N	Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Q1	Tinkercad platform is easy to use.	57.1%	42.9%	0%	0%	0%
Q2	I learnt about serial communication between the transmitter and receiver.	57.1%	42.9%	0%	0%	0%
Q3	I am able to implement the sensors and actuators that I needed for my project.	57.1%	35.7%	7.1%	0%	0%
Q4	Tinkercad platform allows me to perform the circuit connections and test the codes effectively.	64.3%	35.7%	0%	0%	0%
Q5	Tinkercad platform allows me to develop and implement solutions for real-life applications.	50.0%	35.7%	7.1%	7.1%	0%
Q6	I can demonstrate my project using the Tinkercad platform effectively.	50.0%	50.0%	0%	0%	0%
Q7	Feedback provided by the lecturer is helpful and timely.	64.3%	35.7%	0%	0%	0%

The results from the survey (Table 4) indicated positive experiences from learners, using the Tinkercad platform. Most learners agreed that the Tinkercad platform is easy to use. From the survey responses for Q2, Q3 and Q6, the learners agreed that they have achieved the desired learning outcomes that the instructor has planned to achieve. Other positive comments received mentioned that Tinkercad platform was interesting, fun to use, and that it was good for beginners.

However, there were some shortcomings in the Tinkercad platform too. It was noted that the rating for Q5 was the lowest among all questions asked in the survey. A further review on the learners' comments and concerns found that there were concerns on the limited selection in the Tinkercad library, and hence it imposed a certain constraint in the type of solutions that learners can develop. It was also not a straight-forward process to create a custom component to use in Tinkercad.

To add on, there was also a lack of security in Tinkercad platform. It was noted that learners enrolled in the same virtual classroom found that they could access each other's work if they knew the nickname used by their classmates. Thus, it will be recommended to the learners that the nicknames used should be personalized and kept for their own usage, to avoid future conflicts.

CONCLUSION

The conversion from lab-based to home-based learning for the project component of the Electronic Communication module was successfully implemented, and learning outcomes were achieved. Learners were able to develop and implement solutions for their identified problem statement despite full-time home-based learning during the pandemic. They were able to go through the entire development process using Tinkercad platform from connecting components on breadboard to writing codes to testing. Some compromises had to be made, such as conversion of wireless RF modules to wired serial connections and to replace certain sensors and actuators with a simple analog or digital input or output.

As revealed by the survey results with the learners, all of them agreed that Tinkercad platform is easy to use and allows them to demonstrate their projects effectively. This provides a convenient platform for them to do a quick prototype of their ideas even though they do not have access to the hardware.

Moving forward, as both lab-based and home-based implementations were able to help learners achieve the learning outcomes and more face-to-face lessons are permitted on campus, a merger of both implementations can be considered. For example, after completing the wireless RF communication between two Arduino boards in campus, learners can be given a task to implement a wired serial communication in Tinkercad. Simulation of certain sensors is also faster in Tinkercad, which can be achieved just by dragging a slider. It can take some time and effort, for example, to raise the temperature from 25^{o}C to 60^{o}C when using an actual temperature sensor. With both implementations in place to complement each other, learners get to use the best of both lab facilities and Tinkercad platform to complete a higher order thinking project.

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