A Hands-on Project to Improve Student Learning Experience in Electronics: Building Ship Storage Room Security System

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Abstract – **Project Based Learning (PBL) approach is known to motivate students to investigate and integrate knowledge of several domains to solve real-life problems. It drives students' intrinsic curiosity to connect isolated concepts to optimize their learning outcomes. Taking the advantages of PBL, a ship storage room security system project was designed and implemented in a junior-level Electronics Lab course at our university. The purpose of the project was to help students to improve their understanding of electronic element characteristics and their abilities to interpret electronic diagrams, configure and operate of electronic equipment. During the project, students needed to (1) design an electronic diagram that is able to detect ship storage room door open/closed status, trigger an alarm system, and reset the alarm system, and then (2) build an integrated circuit on a breadboard by using various electronic elements following the electronic diagram. Students had to dig into different course contents instructed in class and at the same time learn other new knowledge from external resources, such as internet, industrial documents, etc, to combine them effectively to produce a practical solution. It has been observed that the project has successfully led the students to explore the underlying connections of a variety of electronic concepts from class and new knowledge from external resources reaching their increased understanding of electronics and overall course satisfaction. The student survey results indicate the project has demonstrated strong positive impacts on the improvement of their knowledge and skills in electronic elements, diagrams and equipment.**

Index Terms – Electronic Diagram, Integrated Circuit, Project Based Learning, Security System

INTRODUCTION

It is well known that Project Based Learning (PBL) teaching approach motivates students to investigate and integrate knowledge of several domains to solve real-life problems. It puts students in an open environment to convert a passive learning pattern into an active learning pattern [1, 2, 3]. It is through the active learning pattern that students explore the knowledge instructed in class and new knowledge from other resources to close the gap between theory and applications. While each course provided to students at school is usually composed of isolated contents, the real-life problem-solving process relies on the interweaving of them [4]. PBL empowers students to conduct independent research, apply and integrate new and old knowledge and skills to develop viable solutions to specified problems [5]. It further cultivates students' problem-solving instincts and improves their learning process to prepare them to face and solve real-world challenges in their future careers [6, 9].

Evidences in the Science, Technology, Engineering and Mathematics (STEM) education have been widely reported to demonstrate the effectiveness of PBL to drive students' intrinsic curiosity to connect isolated concepts to optimize their learning outcomes. In [7], in order to help students to increase their understandings of multiple engineering courses and to develop their critical thinking ability, a race car project was selected as a semester-long project for juniors involving the hands-on activities to construct and assemble the analog radio controller, the radio transmitter/receiver and the control unit of a race car. Another project on motor operations was introduced to an electromagnetic course to request students to adjust a motor's speed and acceleration and subsequently observe related signal changes on an oscilloscope to achieve the teaching goal to strengthen their understandings of motor, motor control and signal analysis [8]. Moreover, a bridge-building project conducted at Texas A&M University asked students to apply their prior knowledge of physics and mathematics in junction with their artistic creativity to build a small-scale bridge to enhance their understandings of a variety of STEM concepts and further cultivate their interest in STEM [4]. Furthermore, a website ranking project was carried out in a probabilistic analysis course in a computer science curriculum to simulate students' independent research ability to look into Google's various search algorithms to deliver ranking strategies for website owners to achieve students' increased course understandings of existing course complex concepts and emerging popular algorithms [9].

Taking the advantages of PBL, a ship storage room security system project was designed and implemented in a junior-level Electronics Lab course at our university for the purpose to help students to improve their understanding of electronic element characteristics and their abilities to interpret electronic diagrams, configure and operate of electronic equipment. During the project, students needed to

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(1) design an electronic diagram that is able to detect ship storage room door open/closed status, trigger an alarm system, and reset the alarm system, and then (2) build an integrated circuit on a breadboard by using various electronic elements, such as infra sensors, transistors, relay, push button, buzzer, power supply, etc, following the electronic diagram. Students had to dig into the course contents instructed in class and at the same time learn other new knowledge from external resources, such as internet, industrial documents, etc, to combine them effectively to produce a practical solution. After students had completed the project, all project solutions were assessed by the instructor to understand their performance and provide feedbacks to them if any concept misunderstanding or knowledge gap was identified. Additionally, a voluntary student survey was conducted to assess whether the project has improved their knowledge and skills in electronic elements, diagrams and equipment.

The paper is organized as follows. The project description section presents student background and explains the ship storage room electronic security system project. The student activities section discusses the procedure that students followed to design an electronic diagram and build an integrated circuit to solve the project. It also describes a sample project solution from students. The assessment results section provides the observations of the student project performance by the instructor and the student survey results of their learning outcomes. The last section concludes the paper and outlines the future work.

PROJECT DESCRIPTION

The project of building ship storage room electronic security system is part of a junior-level Electronics Lab course for engineering major students at our university. The Electronics Lab course is for one semester and takes 2 hours per week. The prerequisites of the course are Engineering Physics and Calculus. The Electronics Lab course helps students to develop their hands-on experience in electronic elements and circuits, such as resistors, capacitors, series/parallel circuits, logic circuits, filters, rectifiers, transistors, amplifiers, relays, etc. It also helps students to develop their abilities to interpret electronic circuit diagrams which can be composed of complex electronic functional modules and to configure and operate various fundamental electronic equipment, such as multimeter, oscilloscope, etc. Ultimately, the Electronics Lab course is expected to cultivate students' practical knowledge and hands-on skills in electronics and contributes to their confidence in working in electronics in the future.

The project is designed for the last 4 weeks of the course. Earlier before the project in the course, students have completed several basic electronic experiments which prepare them theories and practical experience to be able to conduct independent research to solve the project. While the electronic experiments they have completed earlier are focused on limited electronic contents, students are expected to explore and learn new electronic contents from other external resources, such as internet, industrial documents, etc, and gradually build the underlying relationships of prior and new electronics knowledge to creatively generate a project solution.

The purpose of the project is to help students to further improve their understanding of electronic element characteristics, interpretation of electronic diagrams and configuration and operation of electronic equipment. It requires students to build an electronic security system for a ship storage room to monitor its door open or closed status and trigger an alarm system if necessary. Once the electronic security system is armed and the ship storage room door is closed, the electronic security system turns on a Green LED indicting the door is in a normal condition. Afterwards, if the door is opened unexpectedly, the electronic security system should be triggered. It turns off the Green LED, turns on a Red LED and rings a buzzer indicating the door is in an abnormal condition. The electronic security system can only return to the untriggered state when a reset button is pressed. It means if the reset button is not pressed, even if the storage room door is closed swiftly after it is opened, the Red LED should still be ON and the buzzer should still ring.

Students are provided with a variety of electronic elements at the laboratory. The electronic elements include

- Resistors,
- Infra sensors,
- Buzzer,
- LEDs
- Transistors,
- Relay,
- Push buttons,
- Op-amps,
- Power supply, etc.

The infra sensors are composed of a transmitter and a receiver [10]. Their communication can only happen when the distance between them is not beyond their communication range and there is no obstacle between them. The overcurrent of the infra sensors needs to be considered to avoid burning them out. Similar considerations are needed for other electronic elements. Students must refer to electronic element specifications from external resources in order to use them correctly. The electronic equipment they can use to monitor and diagnose their solutions includes function generator, multimeter, oscilloscope, etc.

In order to complete the project, students are challenged by the problems of what electronic functional modules are needed, what electronic circuits and electronic elements are used, how to integrate electronic functional modules to generate an electronic diagram, how to safely build an electronic security system without burning out any electronic element and how to use electronic equipment to diagnose and solve any possible fault.

STUDENT ACTIVITIES

At the beginning, students designed an electronic diagram to detect the ship storage room door open/closed status, trigger an alarm system, and reset the alarm system. The procedure that students followed was,

- Design one electronic module to monitor the ship storage room door open/closed status by using the infra sensors. When the ship storage room door is closed, it is positioned between the infra sensors. The communication between the infra sensors is blocked until the ship storage room door is opened.
- Design a second electronic module to detect the communication continuity of the infra sensors. When the communication between the infra sensors is continuous, this module activates the next electronic module.
- Design a third electronic module to trigger and reset an alarm system. If this electronic module is not activated by the previous electronic module, it only turns on a Green LED. If this electronic module is activated, it turns off the Green LED, turns on a Red LED and rings a buzzer. The Red LED and the buzzer can only be deactivated after a reset button is pressed. It means if the reset button is not pressed, even if the door is closed swiftly after it is opened, the Red LED and the buzzer keeps being activated.
- Integrate all three electronic modules to generate an electronic diagram.

Next, based on the electronic diagram, students built an integrated circuit on a breadboard by using various electronic elements, such as infra sensors, transistors, relay, push button, buzzer, power supply, etc. Students had to test whether the integrated circuit could correctly respond to the ship storage room door open/closed status change. If any undesired response was noticed, students would conduct fault analysis by using multimeter, oscilloscope, etc. The faults could be related to the implementation of any electronic element or originate from the integrated electronic diagram designed at the beginning. Once the faults were cleared, the final integrated circuit was regarded as the project solution.

Figure I illustrates a sample electronic diagram designed by students.

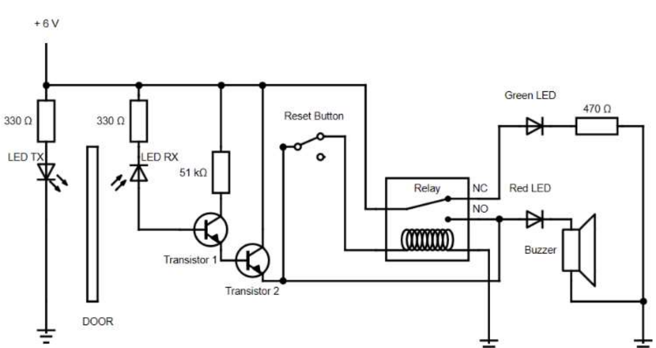

FIGURE I
SAMPLE ELECTRONIC DIAGRAM DESIGNED BY STUDENTS

In Figure I, the first electronic module to monitor the ship storage room door open/closed status is composed of the infra sensors (LED TX and LED RX) and the two 330 Ω resistors. The LED TX is the transmitter and the LED RX is the receiver. Each 330 Ω resistor is chosen and placed in a series relationship with one of the infra sensors to avoid overcurrent to burn out the infra sensors. The door symbol placed between the infra sensors represents the storage room door is closed.

The second electronic module to detect the communication continuity of the infra sensors is composed of the two transistors and the 51 kΩ resistor. If the door symbol is removed from Figure I, the communication between the infra sensors will be continuous. Then the LED RX will allow current to flow to the base pin of the first transistor resulting in the current flow from the collector pin to the emitter pin of the first transistor. Subsequently, the second transistor will start to supply power to activate the next electronic module.

The third electronic module to trigger and reset an alarm system is composed of the reset button, the relay, the Green LED, the 470 Ω resistor, the Red LED and the buzzer. If there is no power coming from the previous electronic module to the relay, the normal closed (NC) switch within the relay is engaged to turn on the Green LED. Once there is power coming from the previous electronic module to the relay, the NC switch within the relay is disengaged to turn off the Green LED and the normal open (NO) switch within the relay is engaged to turn on the Red LED and ring the buzzer. The wire coming out of the NO switch within the relay latches the states of the red LED and the buzzer if the storage room door is closed swiftly after it is opened. The states of the red LED and the buzzer can only be changed when the reset button is pressed to break the latching.

Figure II shows the sample integrated circuit built by students based on the electronic diagram in Figure I. A battery was used in the integrated circuit to represent the storage room door.

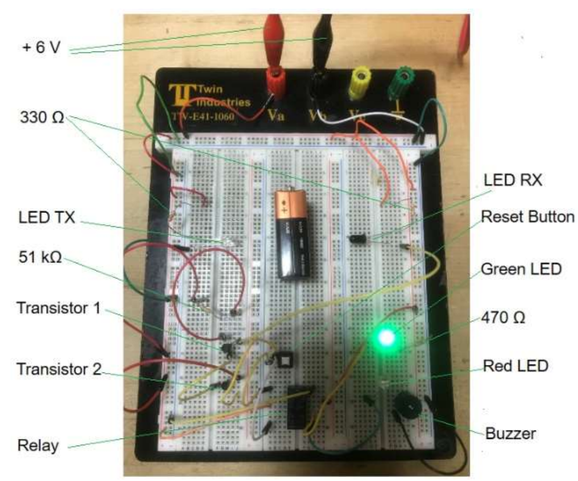

FIGURE II
SAMPLE INTEGRATED CIRCUIT BUILT BY STUDENTS

Figure III demonstrates the responses of the integrated circuit in Figure II to four scenarios in a sequential order, which are (a) when the storage room door is closed, (b) when the storage room is opened, (c) when the storage room door is closed swiftly after it is opened and (d) when the integrated circuit is reset.

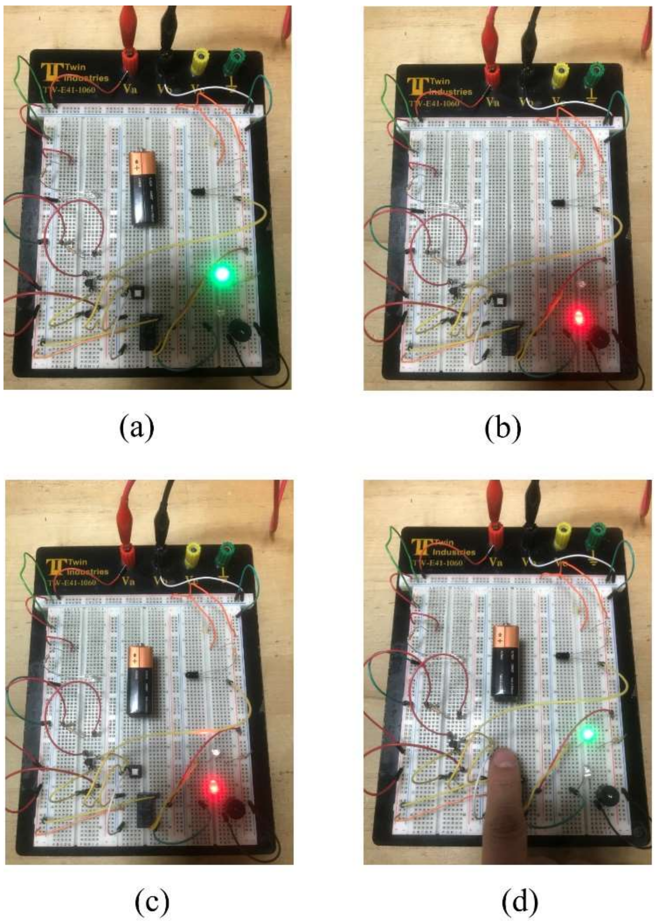

FIGURE III

THE RESPONSES OF THE INTEGRATED CIRCUIT TO A SEQUENCE OF SCENARIOS: (A) WHEN THE STORAGE ROOM DOOR IS CLOSED, (B) WHEN THE STORAGE ROOM DOOR IS OPENED, (C) WHEN THE STORAGE ROOM DOOR IS CLOSED SWIFTLY AFTER IT IS OPENED AND (D) WHEN THE INTEGRATED CIRCUIT IS RESET

In Figure III (a), when the battery was placed between the infra sensors representing the storage room door was closed, it was seen that the Green LED was ON. In Figure III (b), when the battery was removed representing the storage room door was opened unexpectedly, it was noticed that the Green LED went to be OFF, the Red LED went to be ON and the buzzer started to ring. It was confirmed that the integrated circuit successfully caught the storage room door status change. In Figure III (c), when the battery was placed back between the infra sensors representing the storage room door was closed swiftly after it was opened, it was noticed that the Green LED kept OFF, the Red LED kept ON and the buzzer kept ringing. It was confirmed that only closing the ship storage room door without pressing a reset button would not return the state of the integrated circuit. In Figure III (d), once the reset button was pressed, the integrated circuit returned to the untriggered state. The Green LED, the Red LED and the buzzer returned to their original states in Figure III (a).

ASSESSMENT RESULTS

In the spring semester of 2019, 36 engineering major students participated the project in the junior-level Electronics Lab course at our university. The students were divided into 18 groups, each of which was composed of 2 members. After they had completed the project, all their project solutions were assessed by the instructor to understand their performance and provide feedbacks to them if any concept misunderstanding or knowledge gap was identified. Additionally, a voluntary student survey was conducted to assess whether the project has improved their knowledge and skills in electronic elements, diagrams and equipment.

Based on the instructor's assessment, it has been observed that the project has successfully led the students to explore the underlying connections of a variety of electronic contents from class and new knowledge from external resources reaching their increased understanding of electronics and overall course satisfaction. Among the 18 project solutions submitted to the instructor, (a) 8 out of them (or 44.4%) were able to satisfy all the project requirements to detect the ship storage room door open/closed status, trigger an alarm system, and reset the alarm system. (b) 7 out of them (or 38.9%) had minor issues that could be easily corrected. The minor issues included the infra sensors were not well aligned to enable communication between them, the relay power pins were wired inappropriately, the transistor collector pin and the emitter pin were misplaced, the buzzer was not provided enough power to ring, etc. Once the minor issues were informed to the students, they could quickly fix them by themselves. (c) 3 out of them (or 16.7%) had some major issues indicating some concept misunderstanding or knowledge gap. The major issues included the unawareness of overheating electronic elements, the errors to apply transistor, relay, etc. The major issues required extra discussions and examples to help the students to clear them out.

The voluntary student survey contained a list of questions for students to rate their learning experience in electronic elements, diagrams and equipment. Each question was rated on a scale from 1 to 5, with 1 to be "strongly disagree", 2 to be "disagree", 3 to be "neutral", "4" to be "agree" and 5 to be "strongly agree". 32 of the 36 students completed the survey questions.

The first four questions were asked whether the project has improved one's understanding of the electronic elements of infra sensors, transistor, relay and buzzer. Figure IV shows the results, from which it can be seen that 100%, 96.88%, 96.88% and 90.63% of the students either strongly agree or agree the effectiveness of the project to their increased understanding of each electronic element. It is due to the facts that the students had to look into the features of electronic elements and their specifications in order to properly use them when building integrated circuits. The next two questions were asked whether the project has improved one's ability to interpret circuit diagrams and one's ability to configure and operate electronic equipment. The results are in Figure V. It can be seen that 93.75% and 100% of the students either strongly agree or agree that this project has contributed to their increased competence in circuit diagrams and electronic equipment. Since the students had to design and assemble three electronic modules, they had to exam thoroughly circuit diagrams and also later utilize electronic equipment to monitor integrated circuits. All student survey results indicate the project has demonstrated strong positive impacts on the improvement of their knowledge and skills in electronic elements, diagrams and equipment.

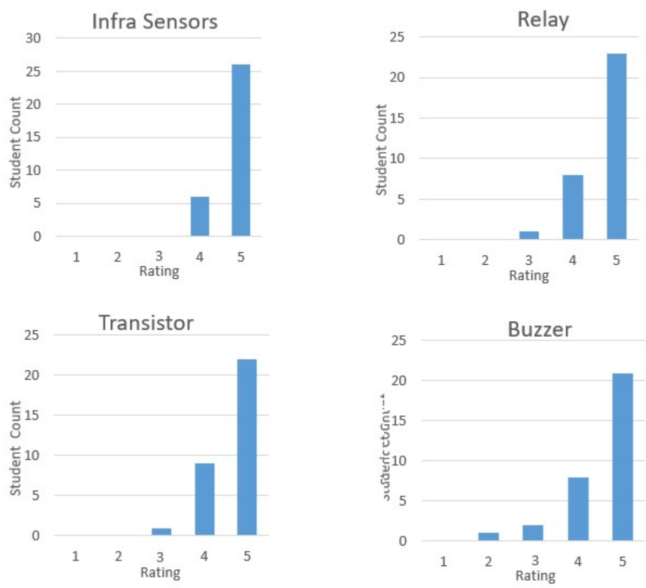

FIGURE IV
STUDENTS SURVEY RESULTS ON ELECTRONIC ELEMENTS

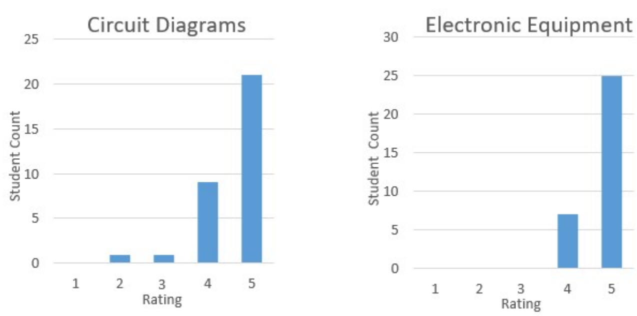

FIGURE V
STUDENTS SURVEY RESULTS ON CIRCUIT DIAGRAMS AND ELECTRONIC EQUIPMENT

CONCLUSIONS

This paper discussed a hands-on project to build ship storage room electronic security system for a junior-level Electronic Lab to increase student learning experience to understand electronic elements, interpret electronic diagrams and configure and operate electronic equipment. Students designed an electronic diagram to detect the ship storage room door open/closed status, trigger an alarm system, and reset the alarm system, and then built an integrated circuit on a breadboard in reference to the electronic diagram to solve the project. The assessment of their project solutions suggested that the project has achieved high student learning outcomes. 44.4% of the project solutions were able to satisfy all the project requirements. 38.9% of them had minor issues that could be easily corrected. 16.7% of them had some major issues that needed extra discussions and examples to be cleared. The student survey results of the project have shown high percentage ratings to demonstrate the strong positive impacts of the project on their learning experience.

The future work can extend the project to include soldering activity to ask students to deliver a PCB board. Another direction is to add an advanced electronic board, such as Arduino, Raspberry Pi, etc, to promote their programming and digital control skills.

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