

Automatic Compartment Temperature Control Project In Electronics Laboratory

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Abstract

The engineering programs at our university are designed to achieve student learning outcomes in maritime engineering knowledge and hands-on experience imposed by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers. After completing the topic of electronics, students are expected to (1) understand the characteristics of basic electronic circuit elements, (2) configure and operate principles of electronic equipment, and (3) interpret electrical and simple electronic diagrams.

Recently, an automatic compartment temperature control project was designed and added in the Electronics Laboratory course to evaluate student learning outcomes in electronics. Different from previous isolated lab experiments, the new project requires students to integrate multiple experiments to design and build complex integrated circuits to solve a practical problem. Students first designed multiple electronic circuit modules to separately implement temperature measurement, temperature comparison and actuator control and then integrated all electronic circuit modules as complete electronic diagrams. Second, they used electronic circuit elements in lab to build integrated circuits on breadboards according to the complete electronic diagrams. Further, they tested the integrated circuits on breadboards to observe whether the integrated circuits can activate or deactivate an actuator in response to temperature change. They could use electronic equipment, such as multimeter, oscilloscope, etc, to diagnose the integrated circuits if necessary.

After the completion of the project, all students' integrated circuits were assessed by the instructor on whether they can measure indoor temperature, compare it with the desired temperature and invoke actuator control to automatically maintain indoor temperature. Additionally, an optional student questionnaire survey was conducted among the students who were participating in the project to assess student learning outcomes. The assessment results show a strong positive effectiveness of the project on understanding, configuration, operation and interpretation of electronics. Student narratives also imply the project led to interest and fun of electronics to them.

Introduction

The engineering programs at our university are designed to achieve student learning outcomes in maritime engineering knowledge and hands-on experience imposed by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers. The graduates from our engineering programs need to be proficient in electronics to solve facility, power and marine equipment problems in their future maritime jobs. A student's performance in

electronics is a critical factor to the success of other engineering courses, such as Electrical Machines, Commercial Boilers, Refrigeration, Power Distribution, etc. After completing the topic of electronics, students are expected to (1) understand the characteristics of basic electronic circuit elements, (2) configure and operate principles of electronic equipment, and (3) interpret electrical and simple electronic diagrams.

All engineering students from Facilities Engineering, Energy Systems Engineering and Marine Engineering programs are required to take a 3-credit Electronics lecture course along with a 1-credit Electronics Laboratory course during their junior year. The Electronics Laboratory course was composed of 10 isolated lab experiments, each of which is mainly focused on one electronic concept, such as the Wheatstone bridge, transistor, filter, operational amplifier, etc. Previously, students were only required to conduct all the experiments once to achieve electronics proficiency. While students can conduct each experiment to understand one electronics concept, it is challenging for them to see the “big picture” of how each experiment is connected with other experiments. It is beneficial for students to work on a practical project which puts them in a broader scope and motivates them to integrate multiple experiments to generate a practical solution.

Recently, an automatic compartment temperature control project was designed and added in the Electronics Laboratory course to evaluate student learning outcomes. Different from previous isolated lab experiments, the new project requires students to integrate multiple experiments to design and build integrated circuits to solve a practical problem. The project needs three functions in a sequential order, which are temperature measurement, temperature comparison and actuator control. Students must consider which of the previous isolated lab experiments can support the three functions. Once the multiple lab experiments are selected, students face the question on how to effectively integrate them together to generate a complete solution, which critically requires them to explore the relationships of multiple lab experiments.

Background

Many universities and colleges have reported project-based learning in engineering courses can help students to explore knowledge learnt in class deeply and connect isolated knowledge to improve student performance [1-5]. One example is a project in an electromagnetic course which enriches students to understand multiple fundamental concepts and results in their overall satisfaction of the course [1]. Another example is an aviation project in an electrical and electronic course. It helps students to develop an integrated understanding of multiple aviation concepts to solve flight tracking problems [2]. Further evidence from [3] shows a race car project in an electronics course can prompt students to dig into over 10 concepts learnt earlier to produce high knowledge understanding of all the concepts.

Inspired by the advantage of project-based learning to link multiple concepts to improve student performance, the project described in this paper was created for the EN3212L Electronics Laboratory course. There are three engineering majors, Facilities Engineering, Energy Systems Engineering and Marine Engineering, at our university. The curricula of all engineering majors

require students to take the EN3212L Electronics Laboratory during their junior year. The contents of the course cover voltage dividers, the Wheatstone bridge, filters, rectifiers, transistors, amplifiers, operational amplifiers, relays, etc.

The corequisite of the EN3212L Electronics Laboratory is the EN3212 Electronics, which introduces the theories of solid-state electronic devices, analog and digital integrated circuits, etc. While the EN3212 Electronics emphasizes the scope and depth of electronics theories, the EN3212L Electronics Laboratory contributes to the development of student hands-on experience. Before entering the two electronics courses, students need to take the prerequisite of SM-2224 Engineering Physics II during their sophomore year, which introduces the underneath physics of electric field and Coulomb's law, Ohm's law and Kirchhoff's laws, Faraday's law and Lenz's law, impedance and phasor, etc.

Project Description

The automatic compartment temperature control project was designed for the last four weeks of a semester. It requires students to design and build an integrated electronic circuit that can automatically activate or deactivate a fan in a ship's compartment to maintain its desired temperature. Given the desired compartment temperature no higher than 20°C , when the actual compartment temperature is above 20°C , the integrated electronic circuit must automatically turn on a fan and an LED indicator. A DC motor in the lab can be assumed to be a fan. A thermistor can be used to sense the actual compartment temperature. When the actual compartment temperature drops to be 20°C or lower, the integrated electronic circuit must automatically turn off the fan (or motor) and the LED indicator.

The student schedule of the four weeks for the project is:

Week One:

- To research on which isolated lab experiments they learnt before can provide ideas to temperature measurement, temperature comparison and actuator control.
- To integrate the selected multiple experiments and draw a complete integrated circuit diagram.

Week Two:

- To read and understand the specifications of electronic circuit elements used in the integrated circuit diagram, such as thermistor, DC motor, operational amplifier, etc.
- To specify the values of all electronic circuit elements in the integrated circuit diagram.

Week Three:

- To build an integrated circuit on a breadboard based on the integrated circuit diagram.
- To test it and conduct fault analysis or adjust the design if needed.

Week Four

- To present the final integrated circuit on the breadboard to the instructor for assessment.

The project is expected to accomplish the student learning outcomes in

1. Understanding the characteristics of basic electronic circuit elements, such as resistors, diodes, LEDs, transistors, thermistors, operational amplifiers, a DC motor, etc.
2. Configuring and operating of electronic equipment, such as an oscilloscope, a functional generator, a multimeter, etc.
3. Interpreting electronic diagrams, such as the Wheatstone bridge, op-amp circuits, transistor circuits, a diode circuit, etc.
4. Applying the knowledge of mathematics, science and engineering to solve an electronics project.
5. Designing and conducting electronic experiments, as well as analyzing and interpreting experimental data.
6. Identifying, formulating and solving an electronic project.
7. Using the electronic techniques, skills and modern engineering tools necessary for an electronic project.

To accomplish the project, students first designed multiple electronic circuit modules to separately implement temperature measurement, temperature comparison and actuator control and then integrated all electronic circuit modules as complete electronic diagrams. Second, they used electronic elements in lab to build integrated circuits on breadboards according to the complete electronic diagrams. Further, they tested the integrated circuits on breadboards to observe whether the integrated circuits can activate or deactivate an actuator in response to temperature change. They could use electronic equipment, such as multimeter, oscilloscope, etc, to diagnose the integrated circuits if necessary.

The electronic circuit diagram of one sample integrated circuit from the students is shown in Fig. 1.

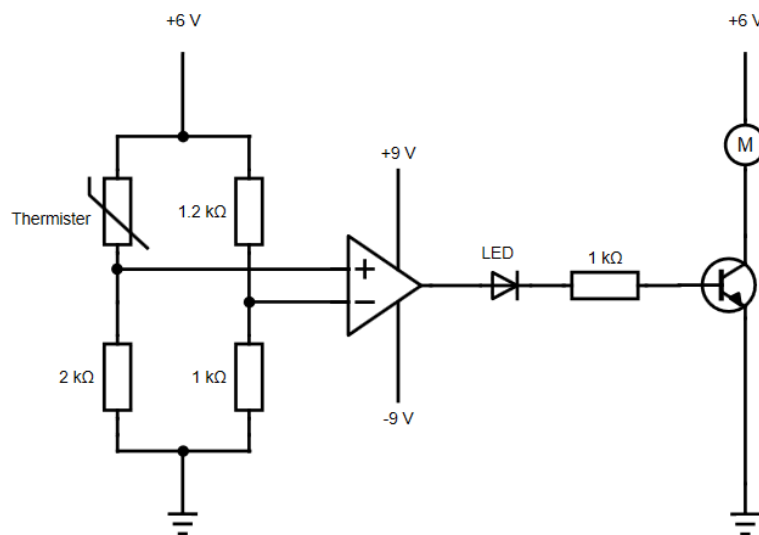


Figure 1. Electronic circuit diagram of one sample project solution from students.

In Fig. 1, the electronic module of compartment temperature measurement is the Wheatstone bridge composed of the thermistor and the three resistors ($2k\Omega$, $1.2k\Omega$ and $1k\Omega$). The thermistor is the Ametherm NTC ACC001 [6], which is a negative thermistor. It means when the actual compartment temperature increases, the thermistor's resistance decreases. In the Wheatstone bridge, the left branch generates a measurement voltage signal representing the actual compartment temperature. The right branch generates a reference voltage signal representing the maximum desired temperature of 20°C .

The electronic module of temperature comparison includes the operational amplifier, the diode LED and the $1k\Omega$ resistor. The measurement voltage signal and the reference voltage signal from the previous temperature measurement module are connected to the positive pin and the negative pin of the operational amplifier, which is a HA1774/PS [7] Op-amp, for comparison. The +9V and -9V power sources are connected to the power pins. When the compartment temperature is above 20°C , the measurement voltage signal is larger than the reference voltage signal. Therefore, the operational amplifier outputs a positive voltage to turn on the LED.

The electronic module of actuator control includes the transistor and the DC motor. The motor is a low-voltage DC motor[8] and is assumed to be a fan in a compartment. When the LED is ON in the previous temperature comparison module, a positive biased voltage is provided between the base pin and the emitter pin of the transistor. Then the collector pin to the emitter pin is continuous and the motor is ON.

Fig. 2 is the integrated electronic circuit built by the students on a breadboard based on the electronic diagram in Fig. 1. It was further tested to demonstrate whether it can activate or deactivate the motor in response to temperature change.

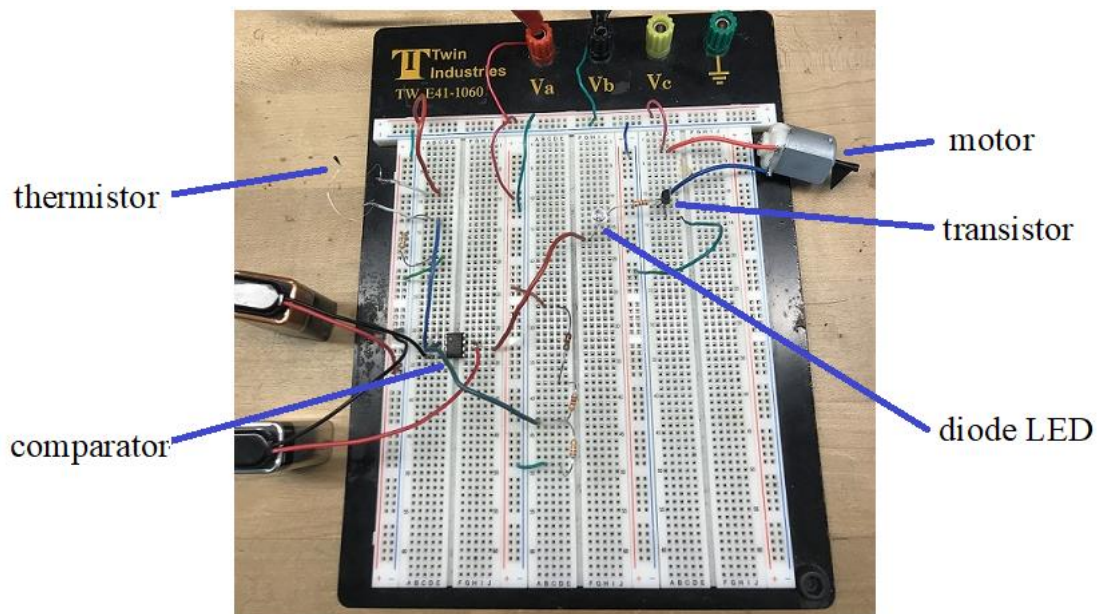


Figure 2. Integrated electronic circuit built on a breadboard based on Fig.1.

Fig. 3 illustrates the testing procedure of the integrated electronic circuit in Fig. 2. At time = 1 s, the integrated electronic circuit was put in an indoor temperature at 20°C . It was observed the LED was OFF and the motor was OFF. At time = 3 s, a student held the thermistor, thus increasing the thermistor's temperature to be above 20°C . It was observed the LED went ON and the motor went ON. At time = 7 s, the student released the thermistor. It was observed the LED went back to OFF and the motor went back to OFF.

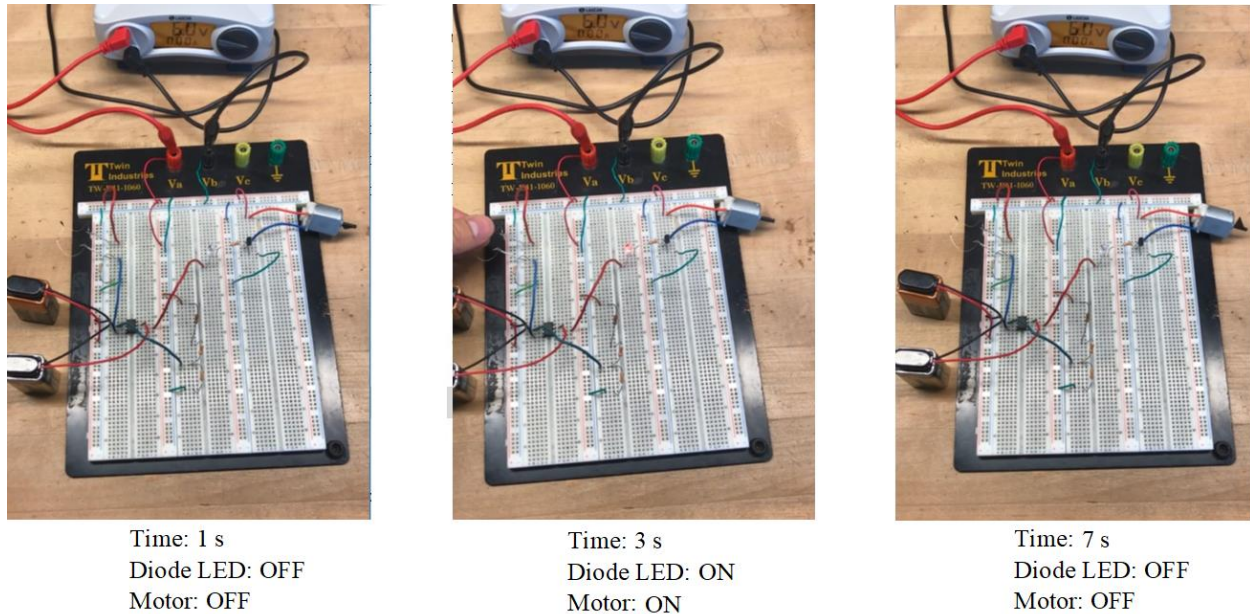


Figure 3. Test of the integrated electronic circuit in Fig. 2 in response to temperature change.

Assessment Results

In Spring 2018, the project was assigned in the Electronics Laboratory course. 36 students from all three engineering majors (Facilities Engineering, Energy Systems Engineering and Marine Engineering) participated the project. The students were divided into groups of 2 members, so there were 18 groups in total.

The instructor assessed all groups' solutions after their completion of the project. The assessment had two stages. In the first stage, as illustrated in Fig. 3, the instructor held the thermistor of a group's solution to observe whether a LED was ON and a motor was activated and then released the thermistor to observe whether the LED went back to OFF and the motor went back to be deactivated. If a group's solution passes this stage, it means this group has effectively solved the project. There is no need for further assessment.

In the second stage, the instructor conducted deep analysis and diagnosis of a group's solution to find out whether three electronic modules of temperature measurement, temperature comparison and actuator control have been created. It helped the instructor to understand whether a group's solution was partial effective with minor mistakes or ineffective with major mistakes.

Among the 18 groups, 7 groups (or 38.9% of the students) have successfully passed the first stage assessment, which means they have successfully accomplished the project; 9 groups (or 50% of the students) have shown partial effective solutions, which finished two of the three electronic modules but had minor mistakes, such as wrong pin wiring of an operational amplifier, neglect of providing power to the collector pin of a transistor, etc, which can be easily corrected; 2 groups (or 11.1% of the students) have shown ineffective solutions, which finished none of the three electronic modules.

An optional questionnaire survey was conducted to assess student learning outcomes in understanding, configuration, operation and interpretation of electronics. Each question was asked to be rated on a scale of 1 to 5, while 1=“strongly disagree”, 2=“disagree”, 3=“neutral”, 4=“agree” and 5=“strongly agree”. Students can also leave narrative comments on the survey if needed. 28 students completed the survey and the summary result is given as follows.

The first question was: “Does the final project make you to demonstrate knowledge and understanding of the characteristics of basic electronic circuit elements”? Fig.4 shows that 14 students rated 5, 12 students rated 4 and 2 students rated 3. The average score is 4.43 with standard deviation of 0.69. This indicates that 92.86% of the students agree that the project helped them to understand the characteristics of basic electronic circuit elements.

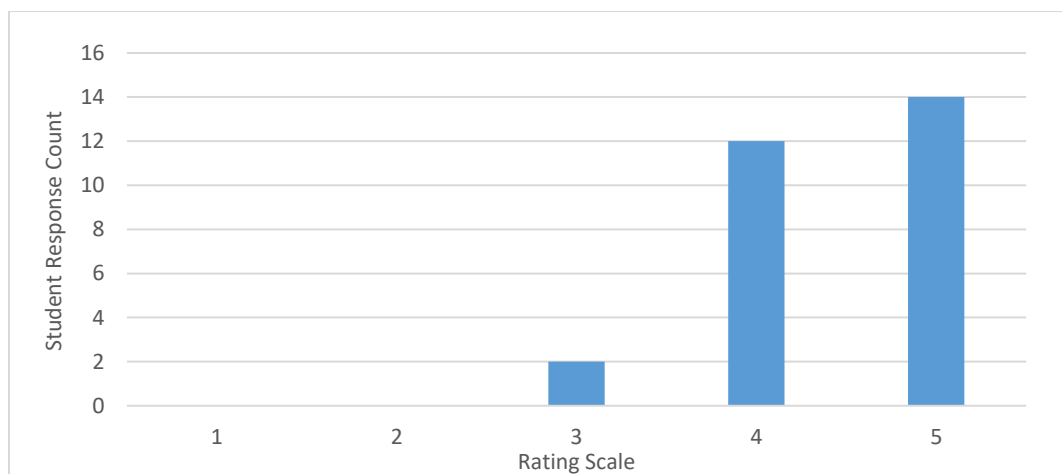


Figure 4. Survey result on knowledge and understanding of electronic circuit elements.

The second question was: “Does the final project make you to demonstrate knowledge and understanding of the configuration and operation principles of electronic equipment”? Fig. 5 shows that 15 students rated 5, 10 students rated 4 and 3 students rated 3. The average score is 4.43 with standard deviation of 0.63. This indicates that 89.29% of the students agree that the project was helpful for them to understand the configuration and operation of electronic equipment.

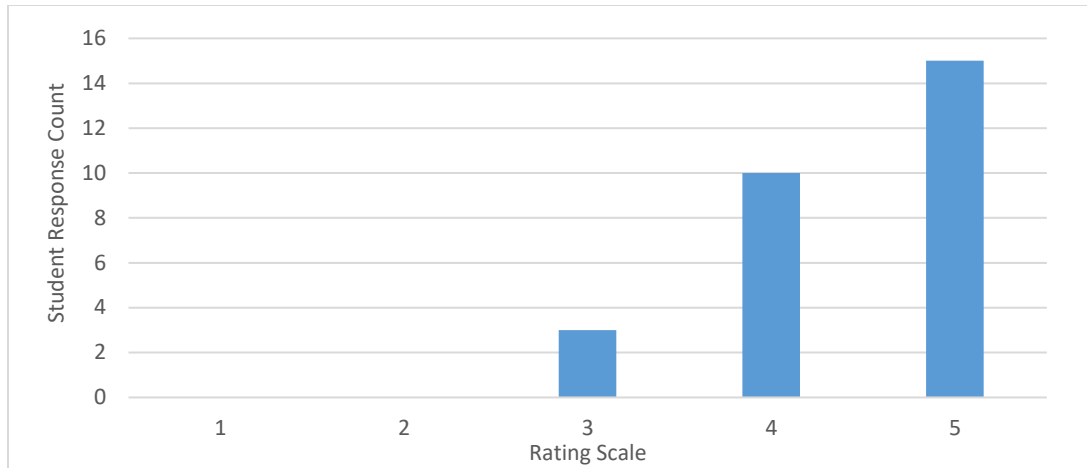


Figure 5. Survey result on configuration and operation of electronic equipment.

The third question was: “Does the final project make you to demonstrate knowledge and understanding of the interpretation of electrical and simple electronic diagrams”? Fig.6 shows that 14 students rated 5, 11 students rated 4 and 3 students rated 3. The average score is 4.39 with standard deviation of 0.69. Consequently, 89.29% of the students agree that the project was useful in aiding understanding of the interpretation of electrical and electronic diagrams.

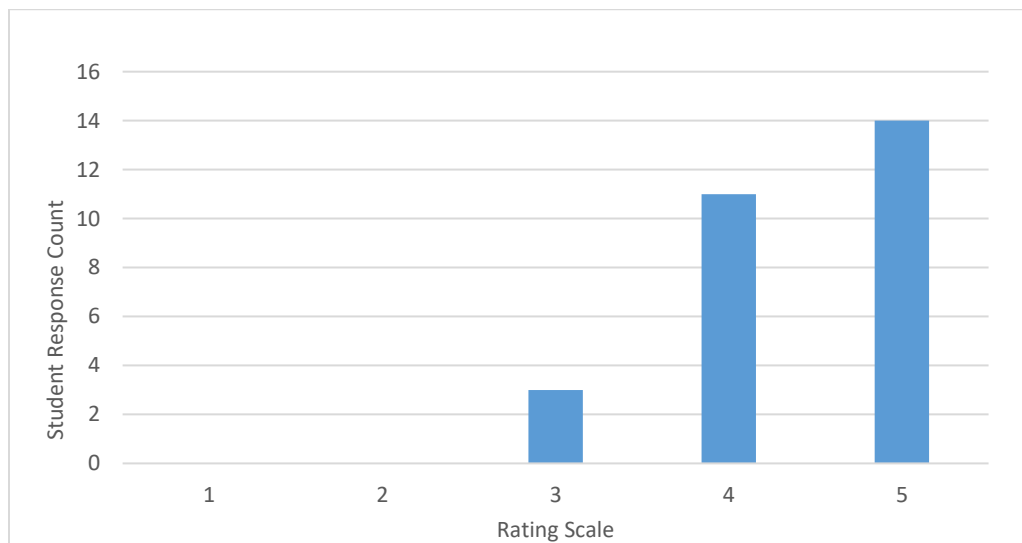


Figure 6. Survey result on interpretation of electrical and electronic diagrams.

The fourth question was: “Overall, does the final project make you to have a better understanding of electronics?” While in previous semesters students were only required to conduct 10 isolated lab experiments to achieve electronics proficiency, this project was assigned as an extra task to them to explore the integration of multiple experiments to solve a practical problem. This question was asked to determine whether the project has improved their understanding of electronic elements, electronic equipment and electronic diagrams in total after

their competition of the 10 lab experiments earlier. The result of this question is in Fig. 7. It shows that 17 students rated 5 and 11 students rated 4. The average score is 4.61 with standard deviation of 0.5. It means all of the students agree that conducting this project helped them gain a better understanding of electronics.

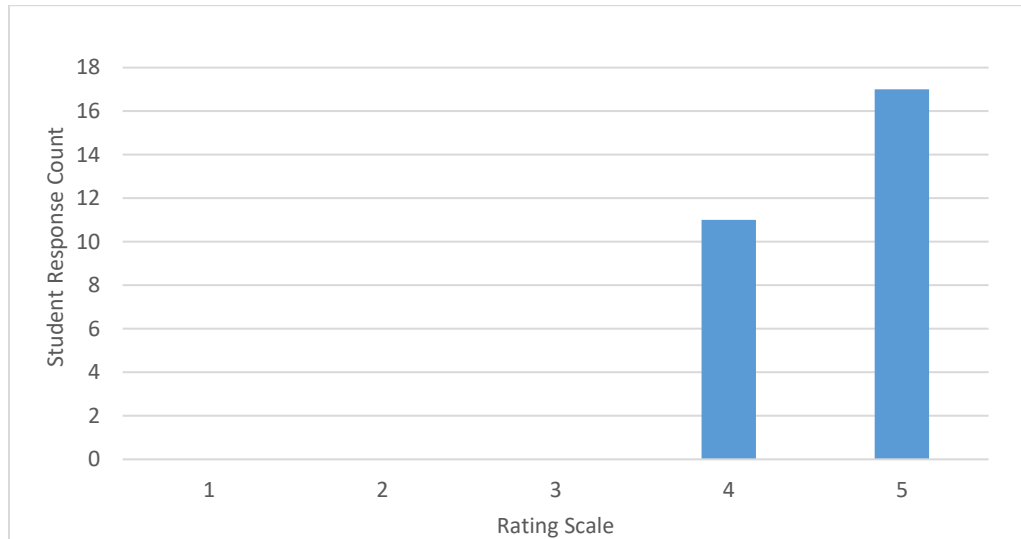


Figure 7. Survey result on overall better understanding of electronics.

At the end of the survey, the students were encouraged to write any comments of the project. This request was made to include additional information to improve projects in the future. Here are some comments from the students:

- Final project was interesting to design and build.
- Project was fun.
- Future projects to have more solutions to solve one problem.
- Great job.
- Personally I liked final project a lot.

Discussion

The instructor's assessment results show that 38.9%, 50% and 11.1% of the students provided completely effective, partial effective and ineffective solutions of the project. The partial effective solutions were not far from the correct ones and could be easily diagnosed and fixed. The common issues were wrong pin wiring of an operational amplifier, neglect of providing power to the collector pin of a transistor, etc. More efforts are needed to explain the pins of an operational amplifier and a transistor. More emphasis can be put on the electronic equipment of multimeter and oscilloscope to enhance student trouble shooting capability. In addition, more interaction with students at an early stage of project can probably reduce the percentage of ineffective solutions.

The student survey results show a strong positive effectiveness of the project on the understanding, configuration, operation and interpretation of electronics after their competition of the 10 lab experiments earlier. It is interesting to notice that even though 2 groups provided ineffective solutions, the survey question 4 result indicates that they all agreed this project improved their study of electronics. 2 students, 3 students and 3 students held neutral opinions in survey question 1, 2 and 3. Further investigation of these neutral opinions can be meaningful.

The student comments imply strong interest and fun this project has brought to them. One opinion “Future projects to have more solutions to solve one problem” indicates that future projects can be designed to have more diverse solutions.

Conclusion

An automatic compartment temperature control project was designed and added in the Electronics Laboratory course to evaluate student learning outcomes in electronics. Different from previous isolated lab experiments, the project requires students to integrate multiple experiments to design and build complex integrated circuits to solve a practical problem. The project description, student schedule and one sample solution from the students were presented. The student survey results show that (1) 92.86%, 89.29% and 89.29% of the students agreed that the project helped them to understand electronic circuit elements, configuration/operation of electronic equipment and interpretation of electrical and electronic diagrams; (2) all students agree that the project improved their understanding of electronics.

Future work of this course will (1) increase efforts to explain the pins of an operational amplifier and a transistor; (2) emphasize the operation of electronic equipment of multimeter and oscilloscope for trouble shooting; (3) initiate more interaction with students at an early stage of project to reduce the percentage of ineffective solutions; (4) design projects of more diverse solutions.

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