Gamification Applied to a Microprocessor Systems Laboratory Activity

Ing. Luis Felipe Zapata Rivera, Embry-Riddle Aeronautical University

Luis Felipe Zapata-Rivera, Ph.D. is an assistant professor at Embry-Riddle Aeronautical University. His research interest are in Online Laboratories and Microprocessors.

©American Society for Engineering Education, 2023

Gamification Applied to a Microprocessor Systems Laboratory Activity

Luis Felipe Zapata-Rivera, Ph.D.
Assistant Professor, Department of Computer, Electrical and Software Engineering
Embry-Riddle Aeronautical University, Prescott Campus

Abstract

Microprocessor Systems Laboratory CEC-322 is a class offered in the programs of Electrical, Computer, and Software Engineering at Embry-Riddle Aeronautical University, Prescott, AZ campus. It includes a set of laboratory activities in which the students are asked to implement real applications of embedded systems. The topics covered in this class include the microcontroller, Serial Communication, Analog to Digital Converters, Timers, Interrupts, and Comparators, among others. All of these concepts are the base for creating real solutions integrating a variety of sensors and actuators.

One laboratory activity uses an Inertial Measurement Unit (IMU) sensor that includes an accelerometer to detect changes in acceleration in different axes. In 2021, the laboratory activity was redefined to include gamification concepts such as time constraints, scores, and multiple modes, among others.

The results in terms of motivation and level of completion have been positive. During the last two semesters, all of the students have completed the implementation of the game with its basic features (time and score), more than half of the students have implemented the high scores feature, and a small percentage have implemented multiple game difficulty levels.

We have found that these types of transformations of academic activities are important because they provide an alignment between the curriculum and the motivators of this generation of students. This paper presents the process of redefinition of the laboratory activity, as well as a comparative analysis of the results of students that completed the activity before and after its redefinition.

1. Introduction

CEC-322 Microprocessor Systems Laboratory, students are asked to implement real applications of embedded systems. These implementations are carried out using a Texas Instruments development board that equips a microcontroller based on an M-family ARM microprocessor [1].

Examples of laboratory activities in this class include implementing a graphic dial system based on the use of potentiometers, implementing a light sensor using a photodiode, and implementing a solution that uses a stepper motor with multiple types of modes of operations among others. All of these laboratory activities include additional features such as a splash screen, a menu of options controlled through serial communication, options for resetting the programs, clearing the screen or the computer terminal, quitting the program, and a “heart bit” LED light that shows the user that the program is active.

The last laboratory activity of the semester needs to be completed in two laboratory work sessions of 3 hours each, it uses an Inertial Measurement Unit (IMU) sensor that includes an accelerometer to detect changes in acceleration in different axes. The laboratory activity prior to the year 2021 asked the student to collect this data from the sensor and represent it on a screen in the form of a circle that moves according to the sensor values, the goal was to build something similar to a bubble leveler.

In the spring semester of 2021, the laboratory activity was redefined to develop a video game that includes elements such as time, scores, and multiple modes, among others. As a result, the laboratory activity now asks the students to implement a game in which a spaceship needs to capture objects in a limited amount of time, where each object captured will increase the player’s score. The students are encouraged to implement additional features such as making the objects disappear after a certain number of seconds, the shorter the objects stay on the screen, the harder it is for the player to capture them, or different types of objects to capture that can give to the player different amounts of points. These additional features increase the difficulty level of the game for the players.

As a bonus activity, the student can implement a view of the top scores and make persistent storing of the data in an external memory unit. It is planned that this laboratory continues evolving, adding extra features such as letting the player go over multiple levels and configurable settings for the games, such as layouts, colors, and shapes.

In this laboratory activity, we asked the students to develop a video game applying the concepts of the course. We have found that the redefinition of this laboratory activity including gamification elements has a positive impact on the student's motivation and provides a better alignment between the curriculum and the motivators of this newer generation of students.

2. Gamification

Game-based learning proposes the use of game principles to improve the students' learning processes. These game-based activities normally include problem-solving and decision-making

[2]. One of the benefits of gamification is the boost in students' engagement which generates an impact on their learning experience [3].

Normally this strategy is applied by including games in the instruction process or incorporating concepts of the class as part of the dynamics of a game the students play individually or in groups. These Game-based learning activities motivate students to learn intrinsically because they can play in scenarios of real life [4].

Researchers have proposed to use game design as an instructional tool, emphasizing how difficult, expensive, and time-consuming, can be to design technological tools that facilitate these processes. Researchers have found ways to simplify this process by creating for instance frameworks using simple tools such as Powerpoint as a game design tool. Showing that performance of groups of students that created games was better than those that did not [5].

Gamifying non-game-like tasks is a resource that can capture the attention and improve the motivation of the students. Designing video games for example may help to enhance the potential for students' metacognitive and strategic thinking skills [6].

3. Laboratory activities redefinition

This section presents details about the previous laboratory activity "Bubble Leveler" (Section 3.1) and its redefinition as the capture crosses video game (Section 3.2), which includes definitions, learning outcomes, and requirements of the activities.

3.1. Bubble Leveler

The laboratory activity learning outcomes were defined as follows:

- Identify the components of the MPU-9150 sensor that includes the accelerometer, gyroscope, and magnetometer.
- Implement the communication between the sensor and the microcontroller using serial communication.
- Apply the engineering design process on a "Bubble Leveler" tool implementation using the hardware and software libraries available for the laboratory activity.

"Bubble Leveler" laboratory activity requirements:

- Numerical mode (sensor values)
- Bubble leveler mode
- Toggle from numerical data to graphical mode and vice versa
- Clear terminal

- Print options menu
- Quit program option
- Written report

The numerical mode presented the values of the accelerometer values on the x, y, and z-axis. These values were used later as the coordinates of the bubble in the bubble leveler mode. This mode adds a cross drawn in the center of the screen representing the (0,0) coordinates reference. If the bubble is located on top of the cross means that the device is being held flat or laying on a flat surface. Images of these two modes are presented in Figure 1.

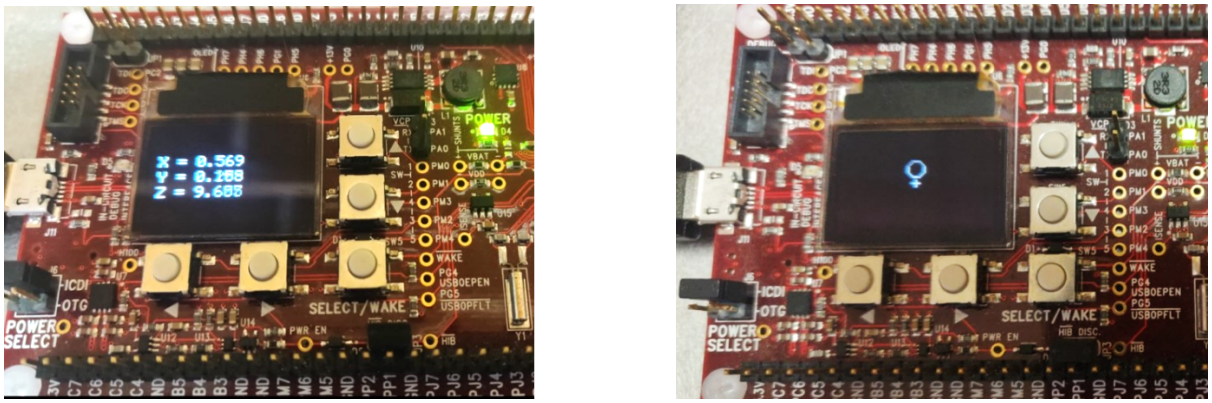

Figure 1. Numerical and graphical modes for “Bubble Leveler” laboratory activity

3.2. Capture crosses video game

The laboratory activity learning outcomes are defined as follows:

- Identify the components of the MPU-9150 sensor that includes the accelerometer, gyroscope, and magnetometer.
- Implement the communication between the sensor and the microcontroller using serial communication.
- Apply the engineering design process in a video game development using the hardware and software libraries available for the laboratory activity.

Capture crosses video game laboratory activity requirements:

- Numerical mode (sensor values)
- Start game option
- Game mode (capture the crosses)
- Print high scores
- Toggle from numerical data to graphical game mode and vice versa
- Clear terminal
- Print options menu
- Quit game option

- Written report

The capture crosses video game also includes a numerical mode requirement, that should print the accelerometer values on the x, y, and z-axis. The game mode should display the game time counting from 30 or 60 seconds to zero seconds, when it reaches zero the game is over. The game should display the player's score, using increments of one every time the player captures a cross.

The game should display a new cross in a random location on the screen. The cross should disappear and appear in another random location when the player's circle center matches the cross center coordinates. Figure 2 presents the numerical mode and the game mode interfaces.

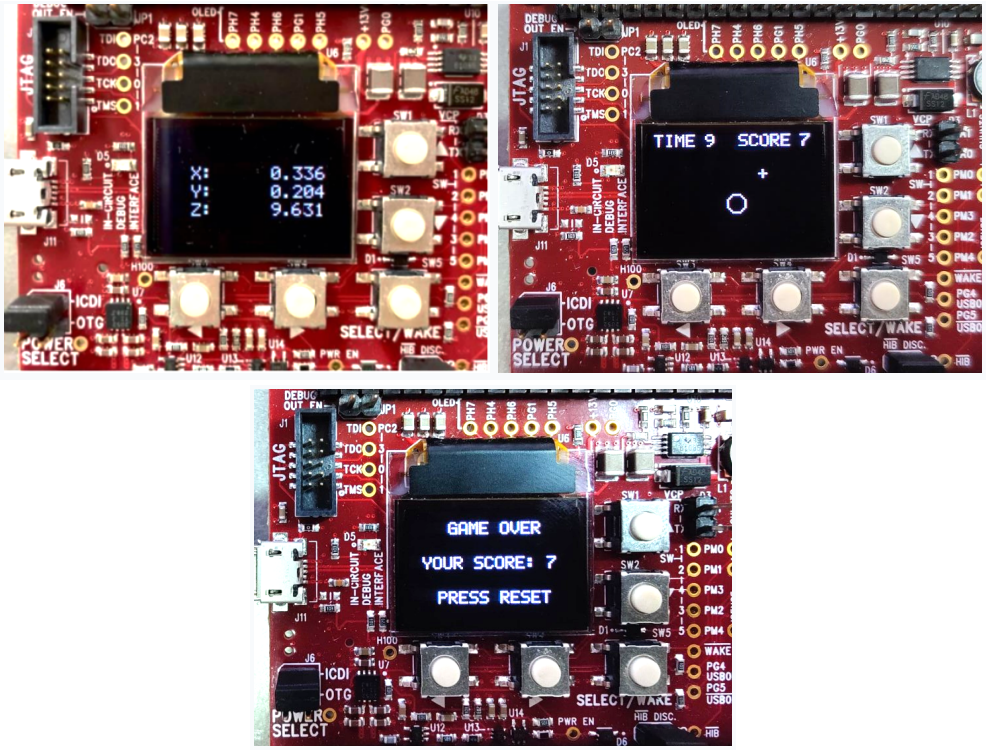

Figure 2. Numerical and game modes for capturing the crosses video game

4. Results

During the 2 years using the new laboratory activity, the majority of the students completed the implementation of the video game. They reported having a good experience and they noticed the difference in working on this activity compared to the previous seven laboratory assignments.

Table 1 shows the number of students that completed all requirements of the laboratory activity, the number of students that partially completed the requirements, and the number of students that did not complete the requirements of the “bubble leveler” laboratory activity.

Table 1. Student results in the laboratory activity bubble leveler

Semester	Completed all the requirements	Most of the requirements	Not completed any of the requirements	Total Students
Fall 2020	19	1	3	23
Percentages	82.6%	4.33%	13%	23

Table 2 shows the number of students that completed all requirements of the laboratory activity, the number of students that partially completed the requirements, and the number of students that not completed the requirements of the laboratory activity capture crosses video game during four consecutive semesters from spring 2021 until the fall semester of 2022.

Table 2. Student results in the laboratory activity capturing the crosses video game

Semester	Completed all the requirements	Most of the requirements	Not completed any of the requirements	Total Students
Spring 2021	18	2	1	21
Fall 2021	24	1	1	26
Spring 2022	13	0	0	13
Fall 2022	18	1	1	20
Percentages	91.25%	5%	3.75%	80

The difference in completion with all the requirements between the laboratory activity before and after the redesign was 8.65% passing from 82.6% to 91.25%. The percentage of students that had not completed any of the requirements showed an important reduction of 9.25% passing from 13% to 3.75%, this indicates that motivation of developing a game might be a factor in having more students trying to complete the new activity.

Some of the comments from the students at the end of the exercise were:

- “The results were that the game runs and works, as intended. As well as it was a lot of fun to figure out and playing with when it got working.”
- “I think this was one of the better exercises as the steps and process was clear and able to be followed.”

- “I found this lab super rewarding, unlike other labs when it was working, I would be like oh cool, and then never touch it again, but this lab gave me a satisfying game to play while waiting for signoff.”
- “It was interesting having such a responsive system and making the game balanced and working was super rewarding. Overall, this was my favorite lab out of all of them.”

5. Conclusions

The video game development requires more time from the students, this is due to the additional requirements the video game has compared with the bubble leveler laboratory and other laboratory activities. However, most of the students were able to complete during the two 3 hour laboratory sessions. A few students had to use some extra time in the laboratory in order to finish the activity.

Due to the positive results of this implementation, we are planning to redefine some of the other laboratory activities to include in their development some gamification concepts that elevate the level of engagement of the students with the laboratory activities.

The proposed laboratory activity is presented during the fall open house event of the university to prospective students, they play the capture crosses video game and are motivated to pursue a career in Engineering.

References

[1]Tiva™ TM4C123G Development Board (Online) https://www.ti.com/lit/ug/spmu357b/spmu357b.pdf [last access: Feb 27, 2023]
[2] I. Chiang, R Shinh, E. zhi-feng liu, and A. jun-yen lee, Using game-based learning and interactive peer assessment to improve career goals and objectives for college students. *Springer-verlag berlin heidelberg* (2011).
[3] K. E. DiCerbo, “Game-Based Assessment of Persistence”. *Educational Technology & Society*, (2014).
[4] C. Aranzazu Suescun, and L. F. Zapata-Rivera, Design of a Mobile Game for Wireless Networks Planning Learning. *LACCEI 2017 Conference.* DOI: 10.18687/LACCEI2017.1.1.530. (2017)
[5] J. P.Siko, and M. Barbour, "Design Research Using Game Design as an Instructional Strategy" (2014). *Education Faculty Publications. Paper 131. http://digitalcommons.sacredheart.edu/ced_fac/131*
[6] J. P. Gee & A. Price (2021) Game-Design Teaching and Learning, Strategies, *34:3, 35-38, DOI: 10.1080/08924562.2021.1896928*