Software Requirements Specification for Digital Design & Computer Organization VR (Virtual Reality) Application

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Introduction

Purpose

This Software Requirements Specification (SRS) document outlines the requirements for the Virtual Reality application designed for a Digital Design & Computer Organization Lab. The purpose of this document is to:

- Define the scope and functionalities of the VR application, ensuring it aligns with the learning objectives of a Digital design and computer organization (CENG205) course.
- Specify the user needs and expectations for interacting with the VR environment to learn the lab concepts.
- Provide a detailed technical reference for developers to build and implement the VR application according to its intended purpose.

- Establish a clear baseline for evaluating the success of the VR application in terms of usability, functionality, gamification, and educational effectiveness.

Scope

This section defines the boundaries of the VR application for the Digital Design & Computer Organization Lab. It outlines what the application will and will not include.

Target concepts: This application will cover the basic logic gates used in CENG205 as an introduction to the course. The user will be able to make circuits to test these logic gates and learn their outcomes. The application will define these gates and other basic circuit components and then introduce a couple of more complicated lab concepts.

Core VR functionalities: The user will wear the head sets to enter a 360 VR environment that represents the lab environment. They will be able to interact with the breadboard as they would usually do in the lab using grip controllers where they grab objects by gripping the controllers and placing the objects in the breadboard.

User interaction modalities: The users will use VR headsets and VR grip controllers to interact with the environment.

Gamification elements: The application includes levels, score, lives, game over condition, hints, Helper NPC, and a Leaderboard.

Feedback mechanisms: The user will track their lives and score during the lab and will be presented with their final score when they finish it. They can also view their placement in the leaderboard.

Multi-user interaction: There will not be direct interaction between users, however all their scores will be collected in a database under their username and all the students will be able to view all the scores in the leaderboard.

Supported VR platforms: Oculus quest, oculus quest2, oculus quest3, oculus rift.

Acronyms, and Abbreviations

Table 01: Acronyms, and Abbreviations

VR	Virtual reality
NPC	Non-player character
SRS	Software Requirements Specification

References

- DIGITAL DESIGN & COMPUTER ORGANIZATION LAB VIRTUAL REALITY ENVIRONMENT
- VR Environment of Digital Design Laboratory: Usability Study

Overall Description

This SRS document provides a comprehensive overview of the VR application designed for CENG205.

Key Features:

- This VR application aims to enhance student learning by offering an immersive and interactive environment to explore Digital design and computer organization lab concepts.
- Users will be able to visualize and interact with the lab components in the VR environment while listening to an NPC ROBO that gives them interactions on how to complete labs within the VR space.
- The application will be designed with usability, gamification, and educational effectiveness in mind.

Target Audience:

This SRS document is intended for various stakeholders involved in the development and implementation of the VR application, including:

- Software Developers: Gain a clear understanding of the application's functionalities and technical specifications for development.
- CENG205 University students: Learn how the VR environment aligns with CENG205 objectives and how it can be integrated into their teaching strategies.
- Usability Testers: Reference this document to design tests that assess the VR application's usability and effectiveness for digital design and computer organization learning.

System Features

The Use-case diagram (Figure1) below presents the features and functions that the VR environment provides for the student.
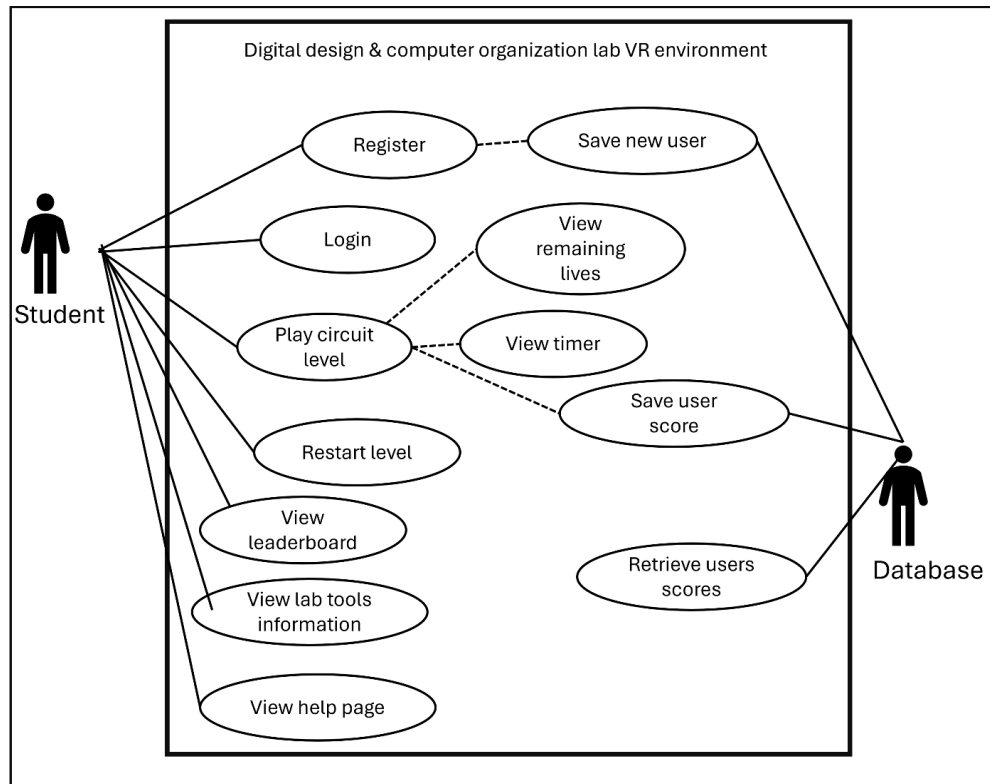
Figure 1: Use-case diagram of the VR environment

Use-case description

ID	1
Name	Register
Description	A user enters their email and password
Actors	**User, database**
Preconditions	Connection to the internet The user does not have an existing account
Main flow of events	1. The user enters their email and creates a new password. 2. The user clicks register. 3. The system registers the new account into the database.

Alternatives	– A1. The user did not enter all required information
	    o A1.1 In case email or password were not entered/ deleted, a message in red is displayed to tell the user to fill in the missing information.
	    o A1.2 Return to step 1
	– A2. The user enters an existing email
	    o A2.1 In case email is already registered, a message in red is displayed to tell the user to re-enter their information correctly.
	    o A2.2 Return to step 1

	– A3. The user does not enter a proper email
	    o A3.1 In case user does not enter a correct email, a message in red is displayed to tell the user to re-enter their information correctly.
	    o A3.2 Return to step 1
	– A4. The user enters a password that is less than 6 characters long
	    o A4.1 In case user enter a password that is less than 6 characters long, a message in red is displayed to re-enter their information correctly.
	    o A4.2 Return to step 1
	– A5. The user is not connected to the internet.
	    o A5.1 The user will not be able to log in.
	    o A5.2 Return to step 1

ID	2
Name	Login
Description	A user enters their newly registered email and password
Actors	**User, database**
Preconditions	Connection to the internet The user does have an existing account
Main flow of events	1. The user enters their email and password. 2. The user clicks login. 3. The system retrieves account information from the database.

Alternatives	– A1. The user did not enter all required information
	    o A1.1 In case email or password were not entered/ deleted, a message in red is displayed to tell the user to fill in the missing information.
	    o A1.2 Return to step 1
	– A2. The user enters an email that does not have a registered account
	    o A2.1 In case email is not registered, a message in red is displayed to tell the user to re-enter their information correctly.
	    o A2.2 Return to step 1
	– A3. The user enters an incorrect password.
	    o A3.1 In case user enter a password that does not match the email entered, a message in red is displayed to tell the user to re-enter their information correctly.
	    o A3.2 Return to step 1
	– A4. The user is not connected to the internet.
	    o A4.1 The user will not be able to log in.
	    o A4.2 Return to step 1

ID	3
Name	Play circuit level (AND)
Description	A user builds a circuit that uses AND logic gate.
Actors	**User, database**
Preconditions	Connection to the internet The user is logged in

Main flow of events	1. The user choses the AND basic logic gate from the Lab List page
	2. The user listens to ROBO instructions.
	3. ROBO (system) define AND logic gate and provide general information (voiced)
	4. ROBO asks the user to place the AND logic gate chip on the breadboard on the highlighted area (hint)
	5. The User grabs the chip and places it on the breadboard and presses next.
	6. ROBO asks the user to place the wires to connect the chip to VCC (pin 14) and ground (pin7) using wires.
	7. The user connects the chip to VCC and ground and presses next.
	8. ROBO asks the user to place the LED and connect it to ground.
	9. The user places the LED and connects it to ground and presses next.
	10. ROBO asks the user to place the switch.
	11. The user places the switch and presses next.
	12. ROBO asks the user to add inputs to the switch:
	   - Input from the switch to pin 13.
	   - Input from the switch to pin 12.
	13. The user adds the inputs and presses next.
	14. ROBO ask the user to add output to the LED for pin 11
	15. The user adds the output and presses next.
	16. ROBO asks the user to connect the switches to VCC and ground.
	17. The user connects switches to VCC and ground and presses next.
	18. ROBO shows the user the truth table of the AND logic gate.
	19. The user tries turning the switches on and off
	20. The LED light up based on the user input.
	21. The user clicks on the Done button
	22. The user is directed to the Done page

	23. The system displays the user score and saves it to the database under the logged in account.

Alternatives	– A1. The user fails to complete any of the tasks asked by ROBO and presses the next button.
	    o A1.1 The user loses one heart (total number of hearts is 3).
	    o A1.2 The user cannot progress until they complete the required task correctly.
	    o A1.2 Return to the previous step.
	– A2. The user clicks the quit button
	    o A2.1 Return to step 1
	– A3. The user loses all of his hearts
	    o A3.1 The user faces the game over page. The game over page provides two options: 1. retry 2. go back to lab list.
	    o A3.2 The user chooses retry and return to step 2
	    o A3.3 The user chooses to go back to lab list and return to step 1.
	– A4. The user is not connected to the internet.
	    o A4.1 The user score will not be saved to the database.

ID	4
Name	View leaderboard (AND)
Description	The user views their score in the AND logic gate level leaderboard.
Actors	**User, database**
Preconditions	Connection to the internet The user is logged in The user played the AND logic gate level
Main flow of events	1. In the lab list page, the user clicks on the AND logic gate leaderboard button. 2. The system retrieves all the account scores from the database. 3. The system displays them starting from the account that achieved lower time. 4. The user looks for their email and views their placement. 5. The user presses the back button.

Alternatives	– A1. The user is not connected to the internet.
	    o A1.1 No scores will be displayed for the user.
	– A2. The user did not play the AND logic gate level.
	    o A2.1 The user will not find their score.
	    o A2.2 Return to step 1

ID	5
Name	View lab components
Description	The user gets to know more about the lab components
Actors	**User**
Preconditions	The user is logged in
Main flow of events	1. In the welcome page the user presses the lab components button. 2. The system displays a collection of tools used in labs. 3. The user chooses a tool. 4. The system zooms in the tool. 5. ROBO displays information about the tool (voiced). 6. The user inspects the tool and clicks on a highlighted area in the tool. 7. ROBO explains more about the area clicked and displays more information. 8. The user presses the back button. 9. The tools go back to normal size and ROBO's detailed information disappears. 10. User press back to leave the page back to welcome page.

ID	6
Name	View help
Description	The user views the help page
Actors	**User**
Preconditions	The user is logged in
Main flow of events	1. In the welcome page the user presses the help button. 2. The system displays overall information about the application and how to use the controllers. 3. The user read the page. 4. The user presses the back button. 5. The user is redirected to the welcome page.

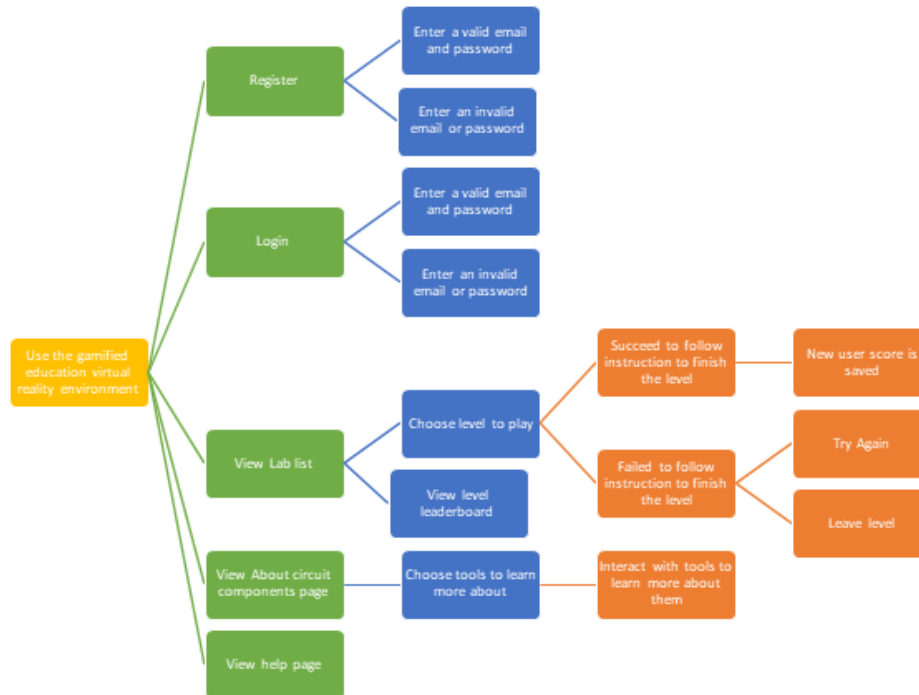Figure 2 shows the hierarchical task analysis of the environment.

Figure 2: Hierarchical Task Analysis

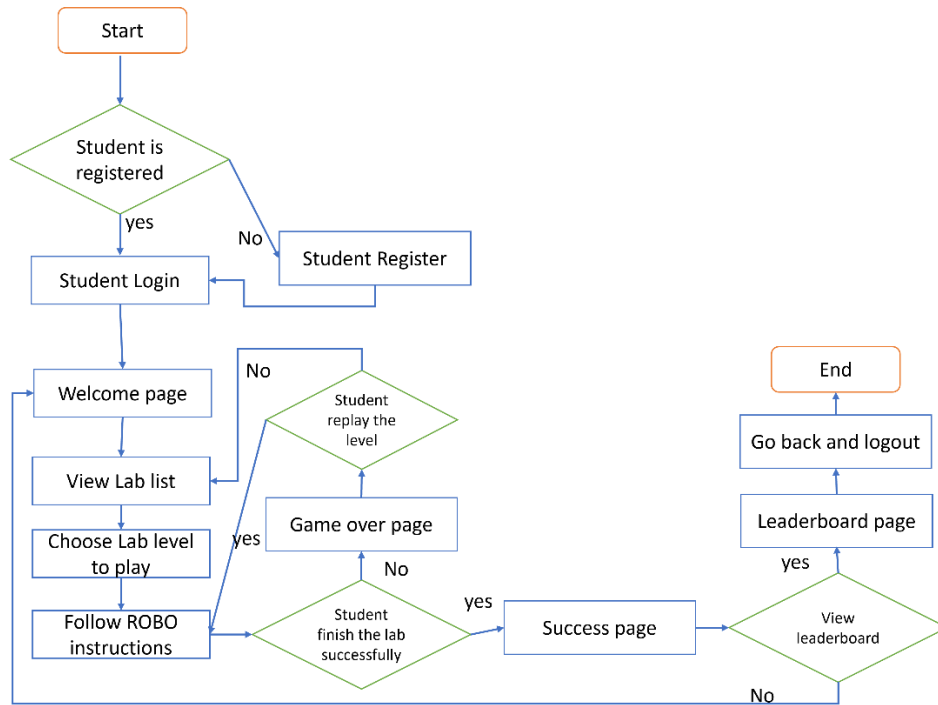Figure 3 shows the workflow of the task of playing a level:

Figure 3: Workflow diagram

Table 1 highlight the gamification elements used in our VR environment application:

Table 2: Gamification elements used.

Gamification elements	Description	Aim
Levels	Different lab levels with different difficulties.	Encourage students to climb up levels and improve their skills.
Score	The Time in seconds spent in every lab.	Increase students' awareness of their performance in levels
Lives (Hearts)	Indicates how many more attempts the student has. The student will have 3 lives for each level.	Remind the students to see practicing and repeated attempts as a chance to master the concepts and techniques involved in the lab.
Game Over condition	When the student reaches 0 lives they face the game over page.	Challenge them to reattempt the lab and practice.
Hints	Highlighted areas of the same shape of object to help students place objects.	Hints unlock understanding, one clue at a time.
Helper NPC	ROBO is an NPC that provides instructions to students.	Guide the students in a fun inspiring way

Leaderboard	Display students' scores (time) from less time to longer times.	Encourage competitiveness to push boundaries, refine skills

Functional Requirements

- The application shall have a main menu.
- The main menu shall have a log in button and a register button
- The user shall be able to register to the application using email and password.
- The user shall be able to login to the application using the email and password.
- The application shall display the welcome page after the user is logged in.
- The welcome page shall have four buttons: View labs, Lab components, help, and logout buttons.
- The user shall choose the help button to view help page.
- The help page shall include an overview of the application.
- The help page shall include a how to use controller section.
- The user shall choose the Lab components button to view lab components page.
- The user shall hear ROBO and see an introduction about the lab components when entering lab components page.
- The user shall be able to see a list of lab components to choose from.
- The application shall provide written and voice information about the component that the user chooses.
- The application shall provide a highlighted clickable area on the component.
- The user shall click on the highlighted area.
- The application shall provide written and voiced specific information about the heighted area of the component.
- The lab components page shall have a back button.
- The user shall go back to the welcome page using the back button.
- The user shall choose the lab list button.
- The lab list page shall include 5 basic logic gate levels (AND, OR, XOR, NAND, NOT) and two more complex levels (half-adder and 1 bit comparator).
- The lab list page shall include a lab button and leaderboard button next to each lab.
- The user shall choose a level and press the lab button.
- The application shall open the lab page.
- ROBO shall provide lab specific interaction in the lab page.
- ROBO instructions shall be displayed and voiced.
- The user shall follow ROBO instructions.

- The user shall use the controllers to grab Objects such as chips, wires, LED lights and switches.
- The application shall provide hints to the user on where to place objects.
- The application shall display the number of lives the user has during the lab level.
- The application shall display a timer during the lab level.
- The application shall have a back button in the lab level.
- ROBO shall not change the dialogue if the user has not completed a task.
- The application shall decrease the number user lives when user does not complete a task successfully.
- The application shall display game over page when there are no lives left.
- The user shall be able to see the student note sheet in each lab level.
- The user shall be able to truth tables for each lab level.
- The user shall be able to see the LED change by the end of each lab level.
- The user shall be able to compare the outcome to the truth table
- The user shall be able to see the Done page and their score after they finish lab level.
- The user shall be able to view their score and placement on the leaderboard page.
- The user shall be able to go back to the welcome page by clicking the back button on the lab list page.
- The user shall be able to logout.

Non-Functional Requirements

- The application shall have background music.
- The application shall have a bule, purple, white and black color pallet.
- The application shall have a robotic voice for ROBO.
- The application shall take no more than 1 second when changing pages/scenes.
- The application shall have sound effects when a live is lost.
- The application shall have sound effects when displaying the game over page.
- The application shall store the users' accounts in an online database.
- The application shall work on oculus headset.

Application interface

Main menu: the main menu includes the VR Digital Design & Computer Organization Lab title, Login, and register option, see Figure 4.

Figure 4: Landing Page with main menu: The player is choosing "Register" option.

Login and register pages: to enable the student to register so that the application can keep track of her score and progress, see Figure 5.

Figure 5: Register page: the player is entering their email and password.

Lab list: a list of all available Labs. Each lab displays options for the student. The options include start the lab and leader board. See Figure 6.
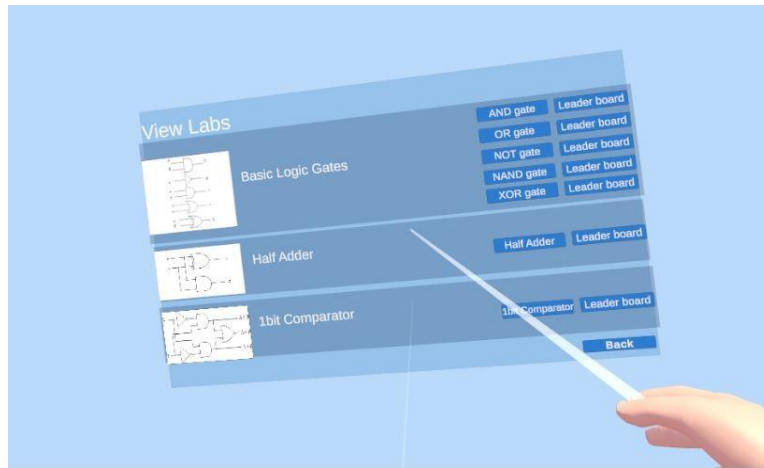
Figure 6: Lab list page.

The lab level: The level includes a virtual robot (ROBO) companion that guides the student through the labs with vocal instructions. The students will be able to use the controllers as hands to carry objects and place them on highlighted areas as guided by the ROBO. They will be able to see hearts on the left side. The hearts represent the attempts to submit the steps. Each lab will provide 3 hearts in which the student is redirected to the game over page if they skipped a step or did not follow the instructions correctly three times. On the right corner of their vision, they will see a timer that starts as soon as the lab starts. The timer will record each student's time score and save them into a leaderboard. The student will have the option to leave the lab. See Figure 6, 7, 8, 9.

Figure 7: Lab Level: AND logic gate
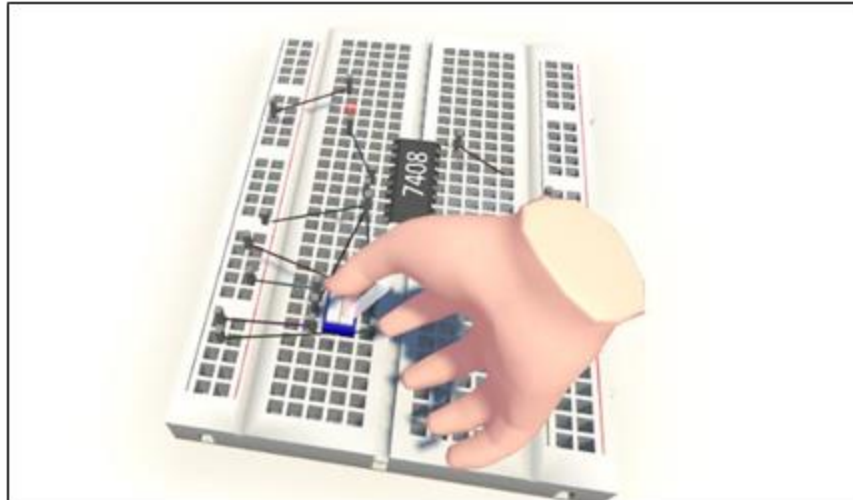

Figure 8: Hint is shown in the breadboard.

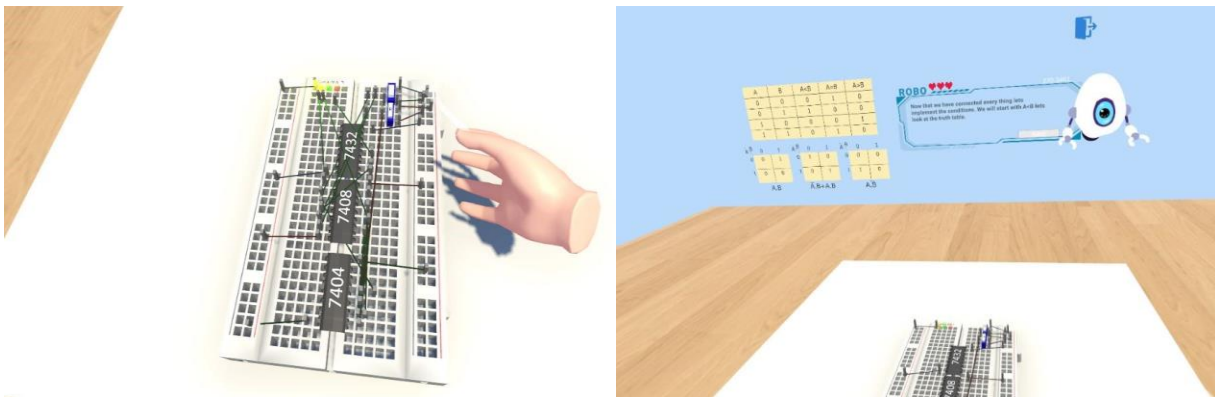*Figure 9: Lab Level: Player finished making a circuit and is trying the switch.*

Figure 10: Lab level: 1 bit comparator: truth table and K-maps hints.

Game over page: this page will be displayed to the student when submitting a failing attempt three times. The page will display an encouraging line for the student and provide an option to leave or retry the lab. See Figure 11.
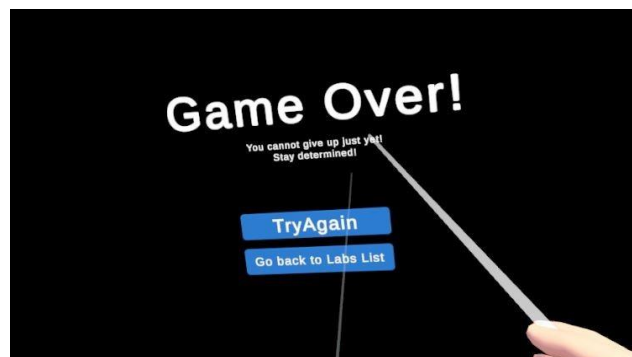

Figure 11: Game over page

Done page: when a student successfully submits a lab A victory page is displayed and the student time score is shown to the student. Students will have the option to try the lab again or leave the lab. See Figure 12.

Figure 12: Done page

Leaderboard page: each lab will have a leaderboard page. This page will display the students' scores. The less time the students spend in the labs, the higher their placement is. See Figure 13.
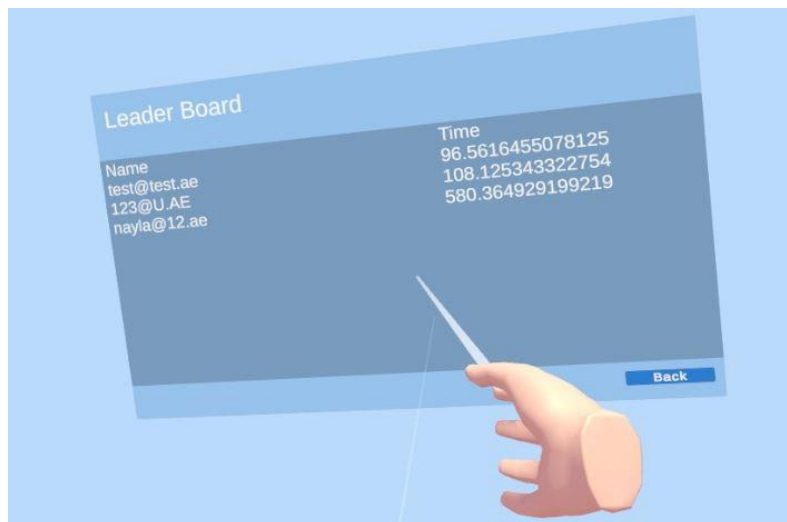
Figure 13: Leaderboard page.

Help page: the help page includes general information about how to use the application and the headset controllers. See Figure 14.

Figure 14: Help page

About circuit components page: this page includes a list of components used in the labs. ROBO would explain each tool when clicked on. Each tool has highlighted areas for the user to click on to get more specific information. See Figures 15 and 16
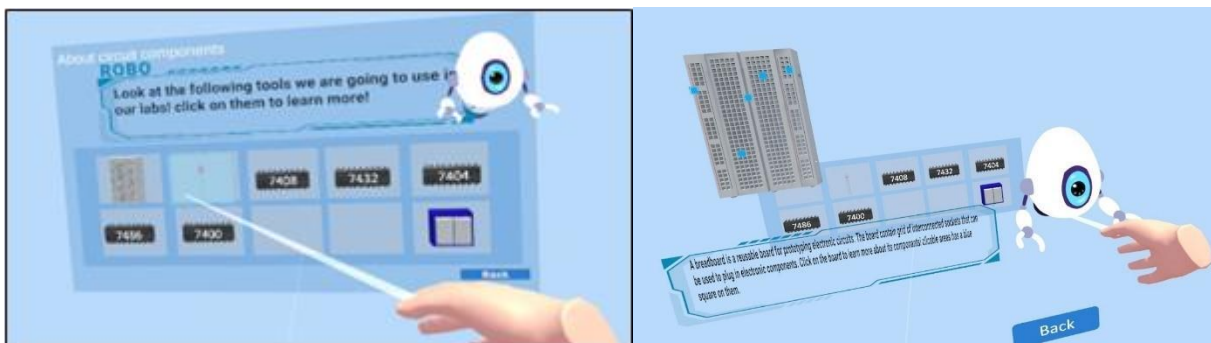

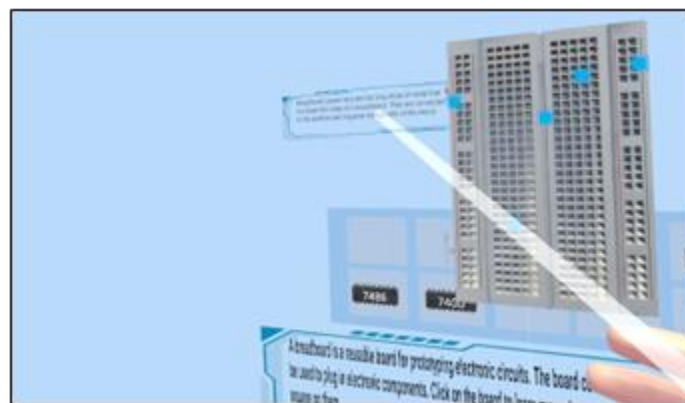*Figure 15: About circuit components page.*

Figure 16: About circuit components page: Player clicks on highlighted area of the tool to learn more.