Developing and Assessing a Customizable Educational Game

Donovan C. Benson Jinghua Zhang

Department of Computer Science
Winston-Salem State University
Winston-Salem, NC, USA
dbenson119@rams.wssu.edu; zhangji@wssu.edu

***Abstract*—This innovative practice full paper describes the creation of a customizable educational game and measures its effectiveness and student enjoyment. The gamification of learning is an effective tool for instructors to help their students learn concepts. Their popularity has slowly increased in classrooms, which has revealed the issue of reusability with many of them for different subjects or concepts. This has led to the rise of customizable video games, which allow instructors to modify the learning aspect of the game to improve its usability in multiple classes. The game, *UnBlocked*, effectively has two modes: Teacher and Student. The mode is determined by the account they use to log in with. The goal of the game is to move the red block out of the puzzle by moving the red and brown blocks within ten moves. After completing the level, the student will have to take a quiz created by their teacher. The student will see their score after completing the quiz and starts the next level. The Teacher mode allows instructors to create in-game quizzes with their own questions for their students. Each quiz has five multiple-choice questions and is saved to Playfab, a backend development platform, after creation with a 5-character string that instructors can give students to access the quiz. The purpose of *UnBlocked* is to provide instructors with a fun way to give quizzes to their students. The game has been used in two classes and evaluated using surveys to determine user sentiment.**

I. Introduction

Finding new ways to engage students in learning is a critical component of enhancing educational outcomes and fostering lifelong curiosity and skill development. Using video games in the classroom can effectively keep students engaged at all levels by providing higher levels of enjoyment and accessibility. There are many ways to incorporate learning into educational video games. The primary strategies are implementing quizzes at strategic checkpoints within the game or creating mini-games that require the students' knowledge of the student learning objective (SLO) to complete. Both strategies reinforce the learning objective and can provide immediate feedback to the student on areas that need improvement. There are two main approaches to game-based learning (GBL): using existing commercial games or developing games for specific SLO [1]. Commercial games typically are easy for instructors to use and provide a better experience to students due to their higher level of polish, but it is difficult to find commercial games for every SLO. A study by Kim and Shin in 2015 [2] showed the effectiveness of using commercial games in classrooms by giving university students in an urban geography course a project to build a city in SimCity and apply theories learned in the classroom to view their outcomes and gain a better understanding of them. Developing games ensures focus on a specific SLO but it is an extremely time-consuming and expensive process that is not practical for most instructors. The reusability of a game is also a major issue shared by both approaches, which has led to the rise of a third approach: customizable video games, which allow instructors to modify the game's learning aspect to personalize the learning outcomes for specific topics as well as improve its usability in different classes. Customizable video games typically allow instructors to modify them by allowing the modification of configuration files that store the information for the desired learning objective or by providing the instructor with a platform to create multiple versions of the same game. The first approach is simpler as it focuses specifically on the modification of the learning information, which can be used in multiple scenarios including mini-games, quizzes, and interactable learning components [1]. The second approach can be more time-consuming but allows instructors to customize the student's gameplay experience as well as the SLO. The integration of these video games into virtual learning environments (VLEs) such as Moodle or Canvas is another challenge that must be considered. To provide students with a fun way to review concepts before taking a quiz, we have developed a customizable game called *UnBlocked*, which allows instructors to create learning tips and quiz questions for their students to use. The gamification of *Unblocked* was created with the intention of being a concept simple enough to be effective with younger age groups while keeping enough of a difficulty increase between levels to remain engaging for older age groups. The goal of this research is to create a game that is easily customizable by instructors, and that is also effective and engaging to students.

II. Related Works

Bontchev [3, 4] created an educational game platform called APOGEE (smArt adaPtive videO GamEs for Education), which allows instructors to create rich educational maze video games. He defines these games as a 3D maze video game with multimedia learning. They are also highly customizable, with the instructor being able to add learning content to the walls of the maze as well as for mini-games that can also be adapted to the learning content [5, 6]. The maze is broken up into individual maze halls which the instructor customizes, allowing them to determine the amount of information in each maze by increasing or decreasing the number of maze halls in the game

[5, 6]. Del Blanco [5] highlights the value of games in learning by describing how games can provide students with a highly realistic environment to practice that is also risk-free. Games also have a higher level of flexibility than most other learning forms, which allows them to have improved assessment techniques and adaptive learning methods [7]. Game-based learning is built upon the idea that people constantly learn through interacting with variable visual environments. This type of learning has already been applied in many fields such as medical and military to provide experience in scenarios that are difficult to consistently reproduce in real life [8]. Freitas [9] conducted a study to measure the pedagogical benefits of using educational video games and found that games were useful for promoting students' motivation and engagement. Connolly [10] also conducted a meta-analysis that found video games contribute to enhancing students' motivation and knowledge acquisition. There are still several obstacles outlined by the Games and Learning Alliance (GALA) roadmap such as the development cost, the hard transition between instructional and game design, which focuses on the integration of learning mechanics into the game mechanics, and issues with a shortage of assessment tools to track the learner's progress among other obstacles [8].

III. Game Design and Development

The game was developed with the Unity game engine and Playfab. The Unity game engine is used to develop 2D, 3D, and virtual reality games. Playfab is a backend development platform that allows developers to easily store game data and handle user registration and authentication along with other tools. Users first create their account by entering an email and password and then clicking the register button to sign up on the main menu as shown in Fig. 1. They can then use their email and password and click the login button to authenticate. The game has two modes: Teacher and Student as shown in Fig. 2. The mode is determined by the account they use to log in with. The Teacher mode allows instructors to create quizzes and learning tips for their students to use before and after completing a level. There are four tips in each set, and they appear at the start of each level. All tips must be read before starting the puzzle to ensure the student reads them before the quiz. Each quiz has five multiple-choice questions and is saved to Playfab after creation with a five-character string used as the access code. The orders of questions and answers are random so each student's quiz will be slightly different. The student mode is the more commonly used mode that allows students to play through the levels and answer the quizzes given by the teacher.

Fig. 1. User Login and Registration

Fig. 2. Tip and Quiz Creator Selector

The game is titled *UnBlocked*, with the goal for the player to move the red block out of the puzzle by moving the red and brown blocks. The player only has ten moves to do this, and if they fail, they will have to restart the level. At the start of each level, the student must enter a tip key to load the tips created by their teacher as seen in Fig 9. They will then have to click on all four "!" blocks as seen in Fig. 3 before the puzzle appears. The four "!" blocks contain tip information as seen in Fig. 4. After completing the level, the player will have to take a quiz created by their teacher. The player will see their score after completing the quiz and start the next level. There are three levels shown in Fig. 5, 6 and 7.Each level adds more blocks, which increases the difficulty for the student. Each level also has one set of tips and a quiz created by the teacher.

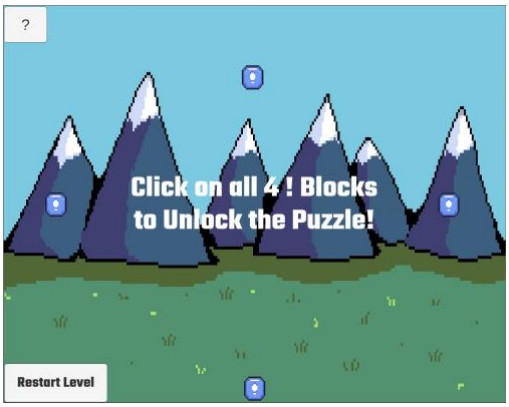

Fig. 3. Four Tips Screen

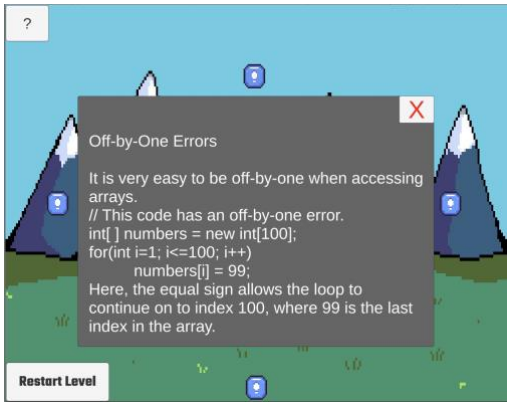

Fig. 4. Tip Information Panel

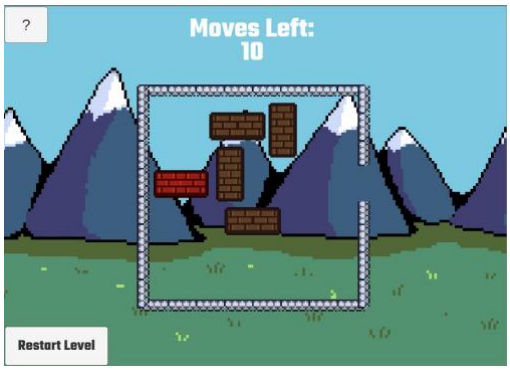

Fig. 5. Level 1 Puzzle

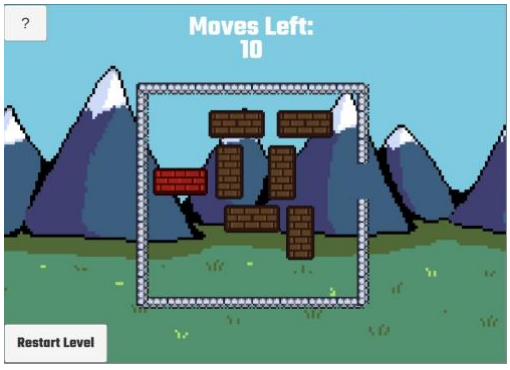

Fig. 6. Level 2 Puzzle

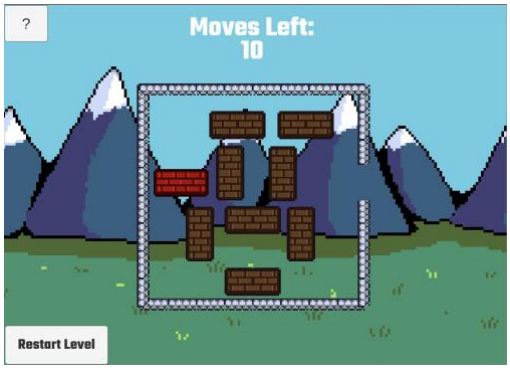

Fig. 7. Level 3 Puzzle

When the teacher logs in with the admin account, a panel appears to let them select either the tip creation or quiz creation panel as shown in Fig. 2. In the quiz creation panel, the teacher can click on the answers and question panels to type questions and their answers as seen in Fig. 8. Instructors can type in any questions they want, allowing for them to create questions for any SLOs for their subject of choice. In the tip creation panel, the teacher can click on any of the four tip panels and type information to reinforce concepts the students will see on the level's quiz as seen in Fig. 9. There is also a how-to-create panel that explains how to use the quiz creator that can be accessed using the "?" button in the top right corner. The quiz data is locally stored in a List of custom type QuestionsAndAnswers. QuestionsAndAnswers contains three variables: Question (type: String) stores the question, Answers (type: String Array) stores the four answers for each question and CorrectAnswer (type: Int) is an integer that stores the position of the correct answer in the Answers array. The CorrectAnswer Integer is always set to 1 because the answer placed in the first answer slot in the quiz creator is always assumed to be the correct answer, but the position of these answers is randomized when the student takes the test. The tip data is first stored locally in a list of four strings to store the tips. Both lists are then separately serialized into JSON objects and sent to Playfab. The quiz question data can be seen in Fig. 11. Students answer the questions by selecting one of the four multiple-choice answers as seen in the quiz panel in Fig. 10. The Student Answers are stored locally in a list of type questionData, which stores the question, the user answer, and the correct answer. The quiz score is then added in after the completion of the quiz. The list is then converted into a JSON object and sent to PlayFab as seen in Fig. 12.

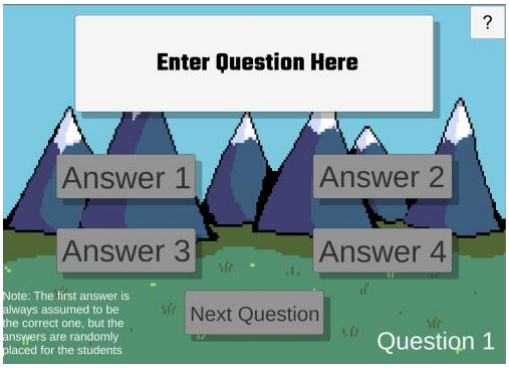

Fig. 8. Quiz Creation Panel

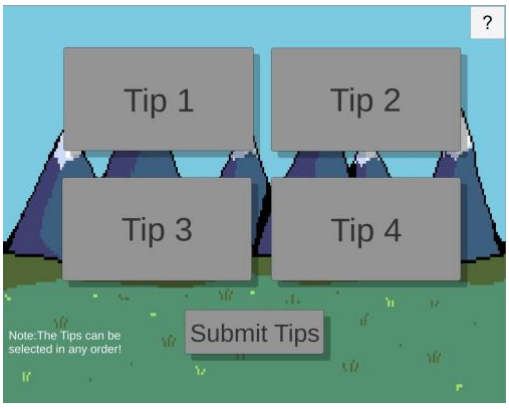

Fig. 9. Tip Creation Panel

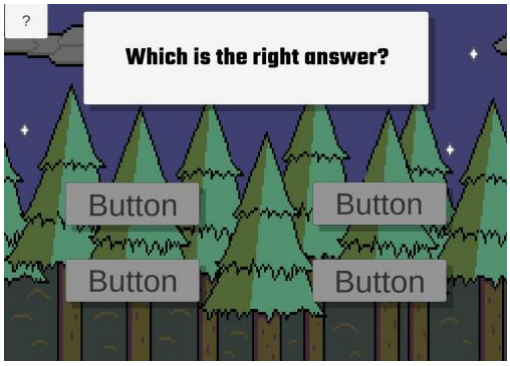

Fig. 10. Quiz Answer Panel

Playfab acts as a database system for both student and teacher data. The data is always sent using the UpdateUserDataRequest method that PlayFab makes available through an API call using their Unity SDK. This allows the data to be stored using key-value pairs which can be easily accessed using a GetUserDataRequest. Playfab also allows you to mark user data as public or private, which was key in the creation of *UnBlocked* as it made it possible to store all teacher data on one account which can be accessed by every student account easily. This allows for more configuration customizability by allowing instructors to give their students any combination of three quiz and tip sets they have previously created for students to play through. *UnBlocked* relies on a wide range of scripts provided by the Unity Game Engine to allow developers to interact with game objects. The scripts have been divided into two major categories: Gameplay, which contains scripts that deal with gameplay and things the user might interact with, and Playfab which handles the management of sending and retrieving teacher and student data from Playfab. Creating the custom data types for the teacher and user as well as creating the quiz creation scene were the most challenging parts of development. The customizability aspect along with retrieving the Quiz data from a specific account presented new challenges.

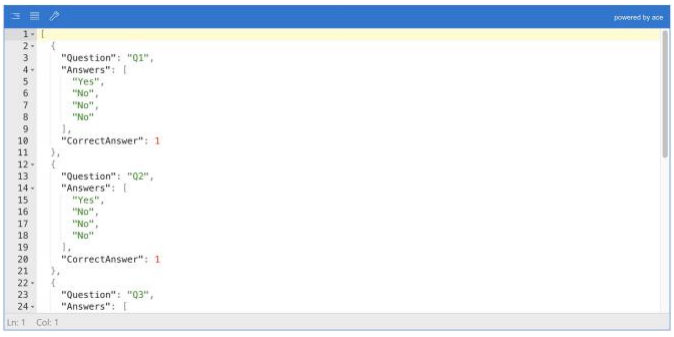

Fig. 11. Quiz Question JSON Object Playfab

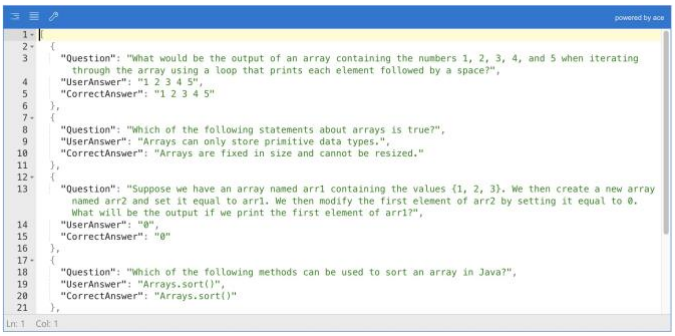

Fig. 12. Quiz Result JSON Object Playfab

IV. Evaluation and Results

To evaluate the effectiveness of the game, 18 students took a quiz with the same questions before playing the game and then gave them the same quiz in-game with relevant tips. The students also completed a survey to measure their sentiments about the effectiveness of the game along with the usefulness of educational video games in general. A focus group was conducted to get more detailed feedback. The game was used in two sections of CSC 1311 Computer Programming II at Winston-Salem State University.

Table I contains the questions given in the pre-quiz which were also the same questions given to the students after completion of the first level. In the in-game quiz, the questions were given to the students five at a time after each level. Students were not told the correct answers after the pre-quiz and the questions in the in-game assessment were given in a random order to mitigate students simply improving on the post-quiz by remembering the correct answers. Fig. 13 displays the pre and post-quiz scores of all the students who fully completed the pre-quiz and the in-game quizzes. Of the 17 students who completed the game, 71 % of the students had a better score on the in-game quiz as compared to the pre-quiz. 88% of students had the same or better score on the in-game quiz.

TABLE I. List of Questions

Questions
1. Array `peoplePerDay` has 365 elements, one for each day of the year. Which assigns the first element with the value 250?

2. Array `peoplePerDay` has 365 elements, one for each day of the year. What is the value of `peoplePerDay[9]`?
`peoplePerDay[9]=5;`
`peoplePerDay[9]=peoplePerDay[9]-3;`

3. Given: `int[] yearsArr = new int[4];`
`yearsArr[0] = 1999;`
`yearsArr[1] = 2012;`
`yearsArr[2] = 2025;`
How many elements in memory does the array declaration create?

4. What is the index of the last element for the following array: `int[] pricesArr = new int[100];`
5. Declare and initialize an array named `myVals` that stores 10 elements of type `double` with default values.

6. What would be the result after the following code is executed?
`int[] numbers = {40, 3, 5, 7, 8, 12, 10};`
`int value = numbers[0];`
`for (int i = 1; i ¡ numbers.length; i++) {`
`if (numbers[i] < value)`
`value = numbers[i];`
`}`

7. What would be the result after the following code is executed?
`int[] numbers ={50, 10, 15, 20, 25, 100, 30};`
`int value = 0;`
 	
`for (int i = 1; i ¡ numbers.length; i++)`
`value += numbers[i];`

8. A partially filled array is normally used___
9. The binary search algorithm___
10. The sequential search algorithm___
11. Given the following two-dimensional array declaration, which statement is true? `int[][] numbers = new int[6][9];`
12. How many elements are in the array declared as: `char[][] streetName = new char[20][50];`
13. What is the value of scores[2][3] in the following array? `int[][] scores = {{88, 80, 79, 92},{75, 84, 93, 80}, {98, 95, 92, 94}, {91, 84, 88, 96}} ;`
14. Which of the following is a correct method header for receiving a two-dimensional array as an argument?
15. If `numbers` is a two-dimensional array, which of the following would give the number of columns in row r?

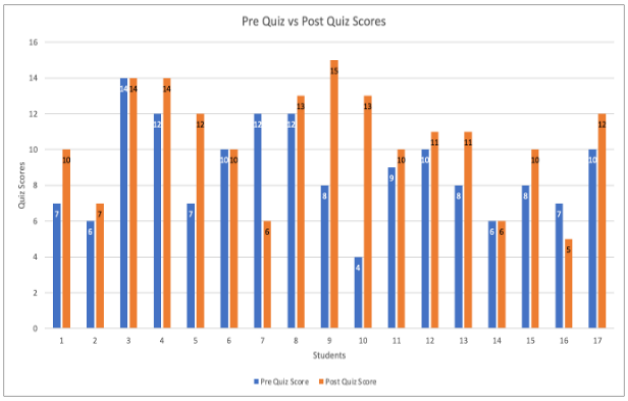

Fig. 13. Pre Quiz vs Post Quiz Scores

Table II lists the students' responses to the survey (Note, no students disagreed with any of the questions). Overall, students seemed to strongly agree with the value of the learning experience through using the game and their engagement levels with the topic were higher. The students also agreed that the game made them feel more confident in the topic after playing and that could be used to help them learn other topics. The students who participated in the focus group provided an interesting perspective into the strengths and weaknesses of the game along with other potential use cases. An initial concern about the game was that students would find inputting a key at the beginning of the level and after completing the puzzle to be slightly monotonous, but they all said that they enjoyed it and that it added to the gamification experience. The students enjoyed the tips before the quiz as they felt it helped them break down concepts that were more confusing to them into smaller pieces that would have normally taken them multiple readings of the textbook to understand. When asked if they would use this game for other classes and concepts, if possible, they all agreed. One student also mentioned that if possible, they would use this as a tool to prepare them for tests to create more of an interactive study guide. The main feature the students wanted to be added to the game was a quiz results screen that would let them see which individual questions they got wrong along with the correct answer instead of the total score they received on each quiz.

TABLE II. SURVEY RESULTS

Questions	Strongly Agree/Agree
I enjoyed learning concepts using this game.	100%
The game engaged me in learning the topic.	100%
I think the learning experience with this game is effective.	94%
After using this game, I feel more confident in applying the learned concepts.	88%
I hope to learn more topics using games.	100%
The difficulty of the puzzle in each level is just right.	76%
The game is fun to play.	94%

V. CONCLUSION

Overall, this paper presented a customizable video game titled *UnBlocked*. The game is developed in the Unity Game Engine. The goal of the game is to provide instructors with an educational video game that could be used for various learning objectives and subjects using any combination of tip and quiz sets that the teacher has created for their students. In the game, the students read learning tips on the current topic before solving a puzzle and then completing an in-game quiz based on the information they just read. This paper discusses the development of the game, including the separate modes for the student and instructor, the scene construction for each level, and the scripts that supported the student and instructor functionalities, including the physics for the puzzles and the creation of quiz and tip information. This paper also discusses the use of PlayFab for storing and retrieving data for the game including login information, students' quiz responses, and the tip and quiz data created by the instructors. The data from the in-game assessments shows that learning using the game was effective as 71% of the students scored better on the quiz after taking the game. The students' feedback from the focus group and survey showed that they were highly engaged with the learning concepts due to the game and would use the game for other classes and concepts if possible. Potential future work for the game would be adding more levels and additional puzzles for each level to keep the gameplay fresh, and adding a results screen after each quiz to show students which questions they got wrong and the correct answer.

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