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Best Practice of Gamification in Block Coding Learning Platform based on Virtual Reality

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Abstract

Due to the government's announcement of the 2025 policy mandating coding education, there is a growing need for effective coding learning methods in elementary education. However, there are few methods available that can easily help younger students understand coding. While text-based coding and visual block coding methods exist, they have limitations. To address these issues, we propose a block coding learning platform that combines virtual reality (VR) technology with gamification elements. The traditional two dimensional (2D) block coding methods have some limitations, so this platform aims to overcome these by providing an environment where learners can intuitively understand and experience coding in a three dimensional (3D) virtual space. The primary goal is to enhance immersive, learner-centered experiences and improve creative problem-solving skills and computational thinking. This study proposes an experimental approach to demonstrate the effectiveness of a learning platform that combines VR technology with block coding. Furthermore, we expect that the VR-based platform will significantly contribute to improving the quality of education and promoting self-directed learning among students.

Keywords: *Virtual Reality, Unreal Engine, Block Coding, Computational Thinking, Gamification*

1. INTRODUCTION

The education policy set to be implemented by the Korean government in 2025 clearly mandates coding education in the elementary and secondary school curricula. As a result of this policy, the time allocated to the 'Information' subject will be significantly increased, with both elementary and middle schools receiving more than double the previous amount of class time [1]. This expansion in teaching hours reflects the rapidly growing societal interest in coding education. The swift changes in the educational landscape especially necessitate the development of innovative and effective coding education methodologies tailored to younger students. While the currently widespread 2D block coding approach is quite useful in the early stages of learning, it reveals significant limitations when advancing to more complex stages or trying to sustain students'

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long-term interests [2]. As a result, an important issue is that this could lead to the creation of "coding dropouts," similar to how some students become "math dropouts" or "English dropouts."

This paper aims to thoroughly analyze the current trends in block coding methods and VR-based block coding both domestically and internationally, identifying their limitations, and proposing a new Virtual Reality (VR)-based block coding learning method. VR-based coding education allows learners to experience and manipulate the results of their code in a three-dimensional virtual space, helping them to understand abstract and complex programming concepts in a more intuitive and experiential manner [3]. By fundamentally improving the VR-based coding education program, this study seeks to enhance the understanding of key concepts that have been lacking in the existing elementary and secondary software education. Additionally, it aims to provide a learner-centered, immersive programming experience through practical engagement. To maximize student interest in coding education, gamification elements are strategically incorporated to maintain and strengthen learning motivation. Through this approach, students are expected to improve their creative problem-solving skills and computational thinking, going beyond merely writing code to deeply understanding and exploring the essence and potential applications of programming.

In Chapter 2, the paper discusses the current state of VR-based coding education as related research. Chapter 3 explains the core components of the newly proposed method, Chapter 4 mentions its practical applications and service flow of the application. Chapter 5 remarks on the conclusions and the direction of future research.

2. Related Works

Park et al. remarks that VR Content Creation Education for Elementary School Students and compare them between a group of students who learned coding using 'Cospaces' and another group that followed a traditional coding education program [4]. 'Cospaces' is a web-based block coding platform founded by a German startup in 2012, which allows users to create content in a three-dimensional space and VR environment [4]. Additionally, by utilizing head-mounted displays (HMDs) such as Google Cardboard, users can view and interact with the virtual spaces they have created.

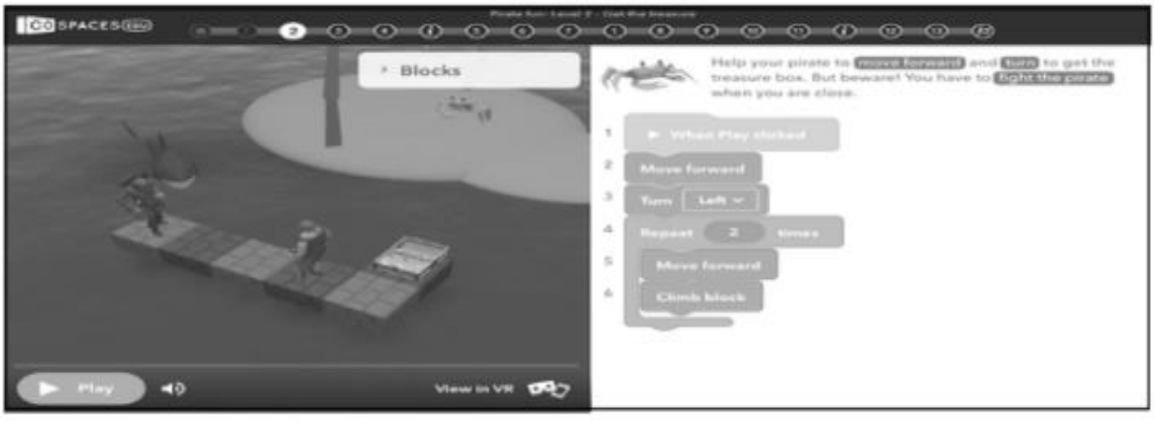


Figure 1.The Block Coding Platform, Cospaces

Figure 1 shows the interface of 'Cospaces,' a platform provided through a website for the American campaign "Hour of Code." It includes a window where debugging can be checked within a three-dimensional environment, and the block coding method used is similar to traditional approaches. In an experiment comparing a group of students who learned coding using 'Cospaces' with another group that followed a traditional coding education program, the results demonstrated that the group using the three-dimensional environment of 'Cospaces' showed significantly better educational outcomes in practical tasks than the group following the traditional program [4].

The study on improving software education using block coding highlights the limitations of current block coding methods, which are constrained within a specific framework and tend to lose student interest, leading to rote memorization and repetitive learning [5]. To address these issues, the study proposes the application of VR technology to block coding and the integration of gamification elements to enhance student engagement. Applying gamification elements is effective in maintaining student interest, as it allows learners to complete their studies through interaction and action [6]. Incorporating game-like mechanisms into non-gaming fields, such as education, has proven to be effective in achieving learning goals.

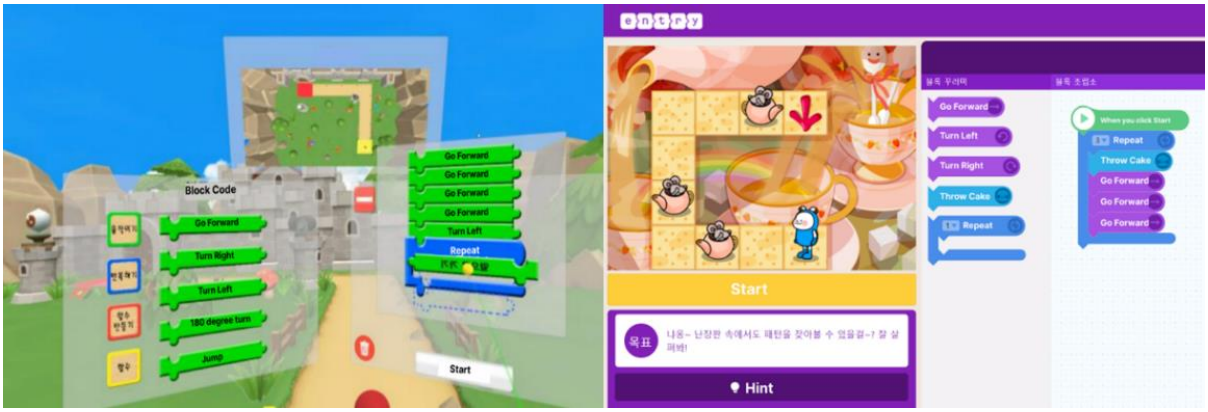


Figure 2. The Existing Virtual Reality based Block coding services

The Figure 2(a) shows a blue loop structure containing a subordinate movement block. Figure 2(b), it is demonstrated that when blocks are dragged and dropped from the left canvas to the right canvas, they are stacked sequentially in the order they were moved. The green blocks control actions such as movement, rotation, and jumping, while the blue blocks serve as loops that contain the green blocks for repetition. Lastly, the yellow blocks function as containers that can include both green and blue blocks, acting as functions. This setup is very similar to the learning interface of Entry, giving it a familiar feel akin to traditional block coding methods.

However, the fundamental learning structure remains unchanged, and the 2D image block coding method is still maintained. When comparing the different aspects of Figure 2(a)(b), it becomes clear that while the platform has shifted from a web service to VR, it still utilizes the three-dimensional space in a flat, two-dimensional manner. This reveals a limitation in fully leveraging the capabilities and effects of VR technology.

3. Our VR-based Block Coding Learning Platform for Gamification

We propose a method to improve a VR-based block coding learning platform by incorporating gamification elements. Based on VR technology, this platform is designed to allow block coding in a three-dimensional space along the X, Y, and Z axes, enabling learners to have a more intuitive and immersive coding experience. Additionally, digital storytelling elements are integrated to make the coding process more engaging for learners and to create an environment that encourages continuous participation [7]. The proposed method is designed for learners to efficiently learn to code independently, focusing on elementary students, as coding and AI education will become mandatory starting in 2025. This approach presents a new educational method in response to these changes.

3.1. Comparison with the Existing Code Learning Platforms

First, we compare various commercialized coding learning platforms. The strengths and weaknesses of each platform are evaluated based on several factors: 2D learning environment, 3D learning environment, VR-based environment, whether it includes storytelling elements, and whether it provides goal-oriented activities (Quest Activities).

Table 1. The Comparison for Code Learning Platforms

	Kooring	Microsoft Makecode	COSPACE EDU	Algorithm City	Lightbot: Programming Puzzles	Sprite BOX	Our approach
2D env.	X	X	X	O	O	O	x
3D env.	O	O	O	X	X	X	O
Virtual Reality	O	X	X	X	X	X	O
Storytelling	X	X	X	X	X	X	O
Quest Activity	O	X	X	X	X	X	O

Table 1 compares various gamified coding learning content currently available in the market. The importance of the comparison criteria lies in the fact that each element plays a crucial role in maximizing learning effectiveness by enhancing the learner's immersive experience and the impact of gamification. Below is an explanation of the significance of each comparison factor.

A 2D environment is commonly used in traditional block coding learning content, where learners solve problems through flat visual information. While this approach is intuitive and straightforward, it lacks interaction with the real world, which can reduce the immersive experience. Therefore, comparing it with 3D and VR environments allows for evaluating differences in learning immersion and effectiveness.

A 3D environment helps learners solve problems by utilizing multidimensional visual information. This setting supports the development of spatial thinking and makes it easier to understand more complex concepts, offering a higher level of immersion than a 2D environment. The experience in a 3D environment expands cognitive abilities and becomes a critical factor in improving the quality of learning [8].

VR immerses learners in a virtual world similar to reality, providing a more realistic learning experience. The VR environment enhances focus and strengthens problem-solving skills through real-time interaction. Additionally, VR has proven effective for long-term memory retention, making it highly applicable to learning content [9].

Quest activities are gamification elements designed to allow learners to accomplish challenges in stages, giving them a sense of achievement. These activities motivate learners to continuously pursue their goals and increase their interest in the learning process. Through quests, learners can recognize their progress, which is vital in sustaining motivation and promoting immersion.

These comparison factors are essential in strengthening immersion and gamification, thereby increasing continuous learner engagement and improving learning outcomes. Analyzing these elements makes it possible to distinguish the new learning methods.

3.2. Service Flow for Block Coding Learning through Gamification

Figure 3 shows the service flows on the VR-based block coding learning platform. This chart sequentially illustrates the critical stages that users will experience as they navigate the program, systematically explaining the learning activities and interaction elements at each stage.

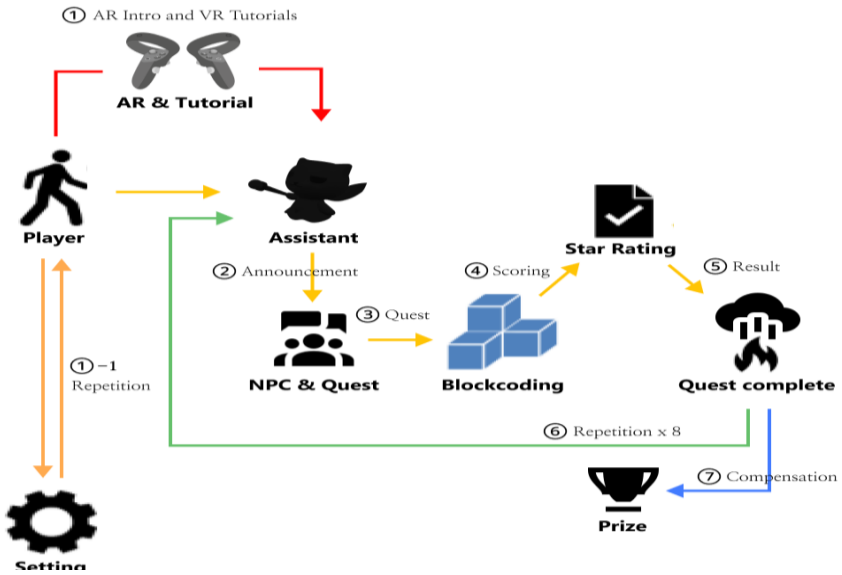


Figure 3. Service Flows on Virtual Reality-based Block Coding Learning Platform

The item labeled as "1-1" represents the settings menu, which is attached to the user's wrist, allowing them to access it at any time during the game. The game's overall flow follows steps 1 through 6, with steps 2 to 5 repeated until all learning objectives are achieved. Upon completing all quests, the user proceeds to step 7, where they receive a certificate, marking the end of the game. Below is an explanation of the functions corresponding to each numbered step.

1-1. Settings Menu: Depending on the angle of the user's wrist, they can access the settings menu at any time to adjust sound, view the mini-map, or exit the game. This menu is always accessible during gameplay, allowing users to make necessary adjustments based on their needs.

1. Game Entry and Tutorial: When the project is launched, the user enters the game through AR, followed by a tutorial designed to teach them how to use the VR controls. This step is essential for familiarizing the user with the controls, ensuring smooth progress throughout the learning process.

2~3. Quest Completion and Learning: Guided by the learning assistant "Luni," the user moves through levels and progresses the story. They accept quests from specific NPCs, select the appropriate data structures, and solve problems through block coding. This process is the main learning activity, gradually enhancing the user's coding skills.

4. Evaluation and Feedback: After comparing the user's coding solution with the optimal solution, feedback is provided through a star rating system. This is a critical process for objectively assessing the user's learning outcomes and identifying areas for improvement. The visual feedback functions as a self-regulated learning program emphasizing self-assessment, significantly impacting students' intrinsic motivation and metacognition. By encouraging learners to reflect on their progress and consider the value of their academic efforts, this process fosters inherent motivation for learning [10].

5. Results Confirmation: The user visually confirms how their coding solution solves the problem through spline components. This visual feedback helps the learner directly see the results of their coding and aids in understanding the learning material.

6. Repeat Steps 2~5 Until All Quests Are Cleared: The user repeats the process of completing quests and learning, gradually improving their coding skills. Upon completing the final quest, they receive a certificate widget, providing a sense of accomplishment and success and fostering a positive learning experience.

4. Our Implementation of a VR-based Block Coding Mechanism

4.1 Block Coding Mechanism with Gamification

The block coding method involves the learner identifying the problem presented on the map and retrieving blocks from the block spawner positioned to their right. The learner then throws the blocks into a magic circle to input the code blocks. When the block touches the magic circle, it disappears, and the block's data is sequentially entered clockwise. Upon pressing the execute button, the learning assistant "Luni" appears in the problem scenario and moves according to the code the learner has written. If the learner incorrectly inputs a block, they can use the back button to delete the blocks in reverse order, starting with the last one placed.

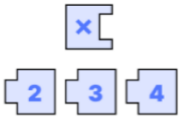
SW Educational elements	Block icon	Actual Block modeling	Function
Sequential structure			Move one space forward
			Turn left in place
			Turn right in place
			Going up one space
			Going down one space
Repetitive structure			Blocks between repetitive blocks are repeated N times

Figure 4. VR Block Coding Mapping Mechanism with Coding Concepts

Figure 4 shows the coding mechanisms and functions associated with each block. The blocks are categorized into two main types: movement blocks and loop blocks. Movement blocks allow the learner to move one step in a given direction, such as forward, backward, turning left, turning right, moving up one step, or moving down. Loop blocks consist of two blocks, which can repeat the blocks placed between them up to four times.

4.2 Leveling Design for Learning Goal

To apply gamification to VR-based block coding, coding concepts that need to be learned are leveled and presented in a progressively challenging manner. Each coding problem is associated with specific learning objectives, and the difficulty increases gradually as learners advance. Below is a summary of the block coding challenges. There are a total of 8 problems, each paired with a corresponding quest, which are alternately carried out across different maps. The maps include the Hall (Main Building), Herbology Classroom, Dormitory, and Village & Magic Forest, totaling four distinct environments. Even before clearing a quest, learners can freely explore all maps, enhancing their sense of freedom and immersion. The table below demonstrates how each quest is linked to level design, highlighting how learners' coding skills are gradually developed via learning objectives and coding problems. This approach explains how learners are guided to acquire coding concepts naturally.

Table 2. Mapping table of learning objectives and SW education elements through quest leveling

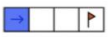
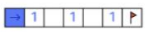
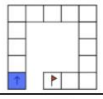
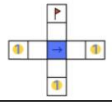
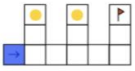
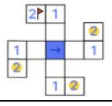
Quest Content	SW Educational elements	Learning objectives	Problem Image
1. Cleaning Up the Dorms	• Sequentialstructure	Connecting a moving block	
2. Finding Lost Items	• Sequential structure	Using Rotation Blocks	
3. Putting out the fire	• Sequential structure • Repetitive structure	Using repeating blocks	
4. Exorcise a fierce animal	• Sequential structure • Repetitive structure	Using rotating and repeating blocks at the same time	
5. Light up the darkened dorm	• Sequential structure • Repetitive structure	Using rotating and repeating blocks at the same time	
6. Watering the Magic Garden	• Sequential structure • Repetitive structure	Getting coins through repeating blocks	
7. Saving Animal on a Tree	• Sequential structure • Repetitive structure	Solving complex repeating block problems	
8.Makting the Magic Potion	• Sequential structure • Repetitive structure	Solving complex repeating block problems, including jump blocks	

Table 2 summarizes the learning content included in each quest, the software education elements to be acquired, and the learning objectives. The first column, "Quest Content," outlines the primary activities of each quest, while "SW Educational Elements" explains the coding concepts covered in that quest. Finally, "Learning Objectives" defines the specific coding skills learners are expected to acquire through the quest. The quests are designed to progress step by step, with early quests introducing basic block coding concepts through simple sequential structures. For instance, in the first quest, "Cleaning Up the Dorms," learners practice fundamental coding skills by connecting simple movement blocks. This helps learners become familiar with the coding environment and understand the basics of block usage.

As the quests progress, they become increasingly complex, introducing advanced concepts such as loops. For example, in the third quest, "Putting out the Fire," learners are taught how to use loop blocks to handle repetitive tasks efficiently. This gradual increase in difficulty allows learners to practice and expand their understanding of new coding concepts. From a level design perspective, each quest is appropriately scaled in difficulty to match the learner's abilities. Early quests are designed to provide learners with a sense of achievement through simple problems, which helps build motivation and confidence, potentially leading to reinforced learning [11]. Subsequent quests incorporate loop structures and complex problem-solving tasks, encouraging learners to apply previously learned concepts and adopt new ones.

The final quest, "Making the Magic Potion," offers an opportunity to comprehensively apply all the learning objectives. In this quest, learners use complex loop structures and additional concepts such as jump blocks, enabling them to demonstrate their overall coding abilities. This table effectively illustrates the critical elements of level design to enhance learners' coding skills gradually. Each quest guides learners through acquiring coding concepts and applying them to problem-solving, ultimately leading to the achievement of

learning objectives naturally and progressively.

5. Conclusion

We propose an improved block coding learning platform based on VR technology, using gamification as an effective learning method for coding education in elementary and secondary schools. The proposed platform strategically incorporates gamification elements to maintain and enhance learner engagement and improve creative problem-solving skills and computational thinking. VR-based block coding learning offers a more immersive, learner-centered experience than traditional 2D block coding methods, enhancing the understanding of coding concepts. However, this study has limitations because it does not cover all coding concepts. Future research should focus on expanding the platform's scope by incorporating various levels and additional coding concepts to strengthen its comprehensiveness. Through these advancements, the development of software education using VR technology is expected to promote self-directed learning among students.

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