# iThinkSmart: Immersive Virtual Reality Mini Games to Facilitate Students' Computational Thinking Skills

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## ABSTRACT

This paper presents iThinkSmart, an immersive virtual reality-based application to facilitate the learning of computational thinking (CT) concepts. The tool was developed to supplement the traditional teaching and learning of CT by integrating three virtual mini games, namely, River Crossing, Tower of Hanoi, and Mount Patti treasure hunt, to foster immersion, interaction, engagement, and personalization for an enhanced learning experience. iThinkSmart mini games can be played on a smartphone with a Goggle Cardboard and hand controller. This first prototype of the game accesses players' competency of CT and renders feedback based on learning progress.

## CCS CONCEPTS

• ; • **Human-centered computing** → Visualization; Visualization design and evaluation methods; • **General and reference** → Cross-computing tools and techniques; Design;

## KEYWORDS

Computational thinking, Computing education, iThinkSmart, Immersive virtual reality, game-based learning, VR, HMD

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## 1 INTRODUCTION

The proliferation of immersive virtual reality (IVR) applications to facilitate learning and teaching is increasingly gaining ground nowadays [1]. IVR application provides a perception of being physically present in a virtual world, tricking the brain to have the sense of real-world experience. Computational thinking (CT) generally refers to the thought process involved in solving problems that are replete in human daily life [2–4]. CT concepts covers numerous aspects, which include problem decomposition, problem abstraction, algorithmic thinking, pattern recognition, recursion, and more. These topics are often taught superficially within a context that may remain abstract and difficult for learners to comprehend. To visualize these concepts of CT, this study developed an IVR application embedded with expedition and mini games to trigger learner's motivation, engagement, and immersive experience [12], while gaining knowledge to improve on problem-solving skills. Aside from visualizing the teaching and learning of CT concepts, many previous tools to facilitate CT rarely can produce quantifiable evidence of students' learning outcomes during the gameplay [5][6], a gap which this study tries to fill. This study is a step towards the augmentation of technology-enhanced learning to supplement the traditional teaching of concepts that are often difficult to comprehend by novice students in programming classes.


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## 2 RELATED WORK

Recently, several studies have developed IVR applications to facilitate education including CT skills, which presents a positive future for the maturing field of virtual environments for learning and teaching at all levels of education [10]. For example, Segura et al. [5] developed IVR application called VR-OCKS to teach students basic concepts of programming through block-based. Kim et al. [9] developed IVR application called GardenVR to support vocational students' design thinking skills. Hooshyar et al. [6] developed an adaptive digital computer game to facilitate CT through personalized features such as visualized hints, feedbacks, and tutorials. Bouali et al. [8] demonstrated the teaching of object-oriented programming (OOP) concepts through visualization within a 3D game-based virtual reality application (Imikode). Malizia et al. [13] developed a virtual reality game - TAPASPlay – to facilitate CT skills such as problem abstraction and decomposition. An experiment with students using TAPASPlay shows that game-based approach can foster CT and collaborative learning [14]. All these studies show the opportunity of deploying immersive virtual reality games in teaching and learning.


**Figure 1: Screenshot of the iThinkSmart VR prototype and interfaces of the mini games**

## 3 METHODS

The design and implementation of the iThinkSmart application adopted a participatory co-design process where the researchers and the students formulated some of the conceptual ideation of mini games and co-designed the expedition scenario. Details about how the conceptualization of iThinkSmart mini games and the co-design process were conducted are demonstrated in Agbo et al. [11]. Besides, the software design process was utilized to design, develop, and implement the iThinkSmart prototype. The core game development technology includes Unity 3D game engine and a Google Cardboard. Because we intend to make the use of iThinkSmart affordable to learners, the application is deployed using a simple Google Cardboard Hand Mounted Display (HMD), an Android smartphone, and a Bluetooth hand controller as shown in Figure 1.

## 4 DEMONSTRATION OF ITHINKSMART FOR COMPUTATIONAL THINKING SKILLS

The iThinkSmart application allows users to access a personalized virtual expedition environment where he/she explores a contextual west Africa setting through the sea and land. The user launches the expedition scene and interactively follows text-based instructions to explore and are presented puzzles, which require a player to solve problems before proceeding on the expedition. Each successfully resolved puzzle provides the player with rewards as scores and unlocks tourist sites of historical relics for the player's enjoyment. Currently, there are three mini games integrated into the iThinkSmart application. The mini games include the River Crossing puzzle, Mountain Patti treasure hunt, and Tower of Hanoi as shown in Figure 1. We demonstrate the CT competency of players of the iThinkSmart mini games by integrating the objective distance model [7]. The objective distance model measures the learner's CT competency defined as:

$$OD_i = \left(\frac{S_i - C_i}{T_i}\right)\left(\sqrt{(C_i - S_i)^2}\right)$$

$OD_i$= Objective distance for an instance i of a learning object;
$S_i$=Satisfactory score for an instance i of a learning object;
$C_i$= Current score for an instance i of a learning object; and
$T_i$=Total score for an instance i of a learning object;
$i = 1,2,3, \ldots$

**Table 1: Computational thinking competency of players of iThinkSmart mini game (River Crossing)**

| Players (P) | Number of trials | Total score | Satisfactory score | Player's current score | Computed OD |
|---|---|---|---|---|---|
| P1 | 1 | 7 | 10 | 9 | 0.1 |
| P2 | 2 | 7 | 10 | 11 | -0.1 |
| P3 | 1 | 7 | 10 | 7 | 1.0 |
| P4 | 2 | 7 | 10 | 7 | 1.0 |

The equation depicts that for any instance of gameplay *i*, the objective distance ($OD_i$) is computed by calculating the differences between the satisfactory score ($S_i$) and the current score ($C_i$), multiplied by the square of their reversed difference and diving the result by the total score ($T_i$). According to Chaichumpa & Temdee [7], the total and satisfied scores can be weighted by experts. For example, we have defined the learning objectives for the River Crossing puzzle with the following weights for the total and satisfactory scores. To obtain the OD, the optimal moves equal the total score = 7; the satisfactory score = 10 (optimal moves increased by 43%). By applying this model, if the OD > 0, the player gained higher competency, if OD=0, the player gained moderate competency, and if OD < 0, the player's competency is poor, and the game would suggest a replay with hints. Table 1 present the results from a few players of the River Crossing puzzle.

As shown in Table1, the first player (P1) attempted to play the game once and was able to solve the problem with 9 moves, which is within the satisfactory level. Therefore, the P1 OD = 0.1 implies moderate CT competency gained. On the contrary, P2 attempted to play the game twice and was able to solve the River Crossing puzzle with 11 total moves, which is greater than a satisfactory score. Therefore, the P2 OD = -0.1, implying that this player has poor CT competency. However, P3 and P4 played the game once and twice, respectively, and gained OD = 1.0, implying that these two players gained high CT competency.

## 5 CONCLUSION AND FUTURE WORK

This study demonstrated the development of an immersive virtual reality application to facilitate CT education. Although this paper is a demonstration paper, the mini games lack extensive evaluation with subjects, which is a limitation. Thus, we cannot conclude on the efficacy of this tool until it has been rigorously evaluated. Consequently, the authors are currently conducting evaluation study with students in a specific discipline and later extend the evaluation to accommodate more settings and context. In addition, the authors hope to improve the iThinkSmart application based on the outcome of the evaluation to include mini games that can teach complex concepts in a visualized environment.

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