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Prototype VR Framework for Visualization and Interaction in STEM & Math Instruction

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Abstract: Interactive VR (Virtual Reality)-based tools can be an effective tool in stimulating interest and reducing cognitive load. Designing the instructional modules in a fun-based interactive desktop VR setting can motivate students to explore new ways to interact with the materials presented. Some of the major underlying STEM and computational thinking concepts involve abstraction, expressions, remixing, and iteration. Students STEM and computational thinking disciplines are employed by a wide range of companies as well as academic programs. While this signifies numerous opportunities for students, it also inherently involves the challenge of preparing students suitably for these opportunities. To assist interactive pedagogy, this study uses a student-focused, user-friendly Virtual Environment (VE) to explain mathematics and computational thinking concepts. The proposed methods may in this framework may offer insights into the use of virtual reality based tools and instructional practices to strengthen STEM education and augment overall computational thinking knowledge.

Key words: virtual reality, desktop VR, computational thinking, mathematics instruction

1. Introduction and Related Work

Of late, computational thinking courses are inevitably becoming an essential foundational aspect of STEM curriculum and programs across the nation. Math and STEM educationalists and other researchers have offered and recommended numerous ways to improve computational thinking instruction. However, students in different STEM disciplines with computational thinking courses continue to face difficulties and the lack of efficient tools to overcome such difficulties can affect students' motivation. Many computational thinking concepts are universal (not specific to only a single platform) and are employed across multiple computational thinking languages (PL). Such basic computational thinking concepts include: data, variables, scope, functions (or methods/routines) loops, iteration, conditionals, recursion, etc. Illustrations are very effective in communicating computational thinking concepts, especially for students with visual learning style preferences. For instance, one of the fundamental computational thinking concepts is loops. Interactive visual examples can help students to rise above the abstract level and proceed to a more concrete level. Integrating Project-based learning (PBL) activities in practical

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perspective is important for realizing the course learning outcomes and leading to student success. To this end, the multi-modal VR framework, utilizing photorealistic and interactive models, facilitates learning and instruction through the use of realistic examples. Visual representations using effective composition can significantly reduce cognitive load and enhance motivation. Colors are an extremely important element of visual communication and hence, composition (Birn, 2006; Davis, 2009). Shapes in combination with colors can be used to convey abstract algebraic concepts in a highly engaging manner to students. In addition to appealing to students with diverse learning styles, such visual examples and interaction enables them to explore and better understand abstract concepts and identify underlying relationships.

To assist interactive pedagogy, this study uses a student-focused, user-friendly Virtual Environment (VE) to explain mathematics and computational thinking concepts. The proposed methods may in this framework may offer insights into the use of virtual reality based tools and instructional practices to strengthen STEM education and augment overall computational thinking knowledge. Not being able to comprehend and appreciate the theoretical fundamentals can seriously affect the performance in future advanced courses as well. This project was driven by the following rationale:

- Making interactive visualizations for foundational concepts,
- Developing materials that are specifically tailored to meet the learning outcomes,
- Developing content that balances theory with lab content.

Facilitating the enhancement of computational thinking literacy, helps with the realization of course learning outcomes and increases the attainment of student career goals. From an academic standpoint, this framework aids the instructional approach to motivate students and engage them in active learning. As computational thinking has been inevitably identified as an essential element of K-12 curriculum, the students' inability to successfully complete computational thinking courses may indeed lead increased dropout rates. The 3D graphical methodology empowers students to overcome any intrinsic inhibitions they may have because of the logic and complexity involved in abstract math and related concepts. The interactive framework stimulates them to explore and understand computational thinking using practical examples and a game-oriented instruction. In their work on VR for math learning and teaching,

Pasqualotti & Freitas (2002) mention that the ability to access and interact with the objects in a VR scene promotes the learning process (Figure 1). The learner can visualize (Figure 2) the 3D models corresponding to the concepts and navigate within the scene in modes such as walk, fly, etc.

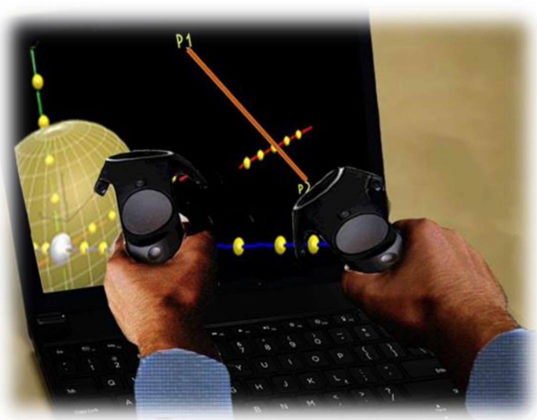

Figure 1 Interaction with a Math (Geometry) VR Module

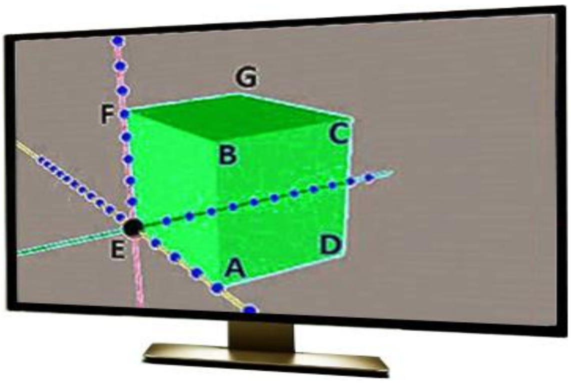

Figure 2 Visualizing 3D Models Using VR Module

2. Methodology

Notwithstanding the variability in the syntax and several other coding differences, many programming languages share common concepts and typically include data types, variables, constants, functions, iterations, and so on. For instance, a variable is a container for data; similar to the real-world, where different types of packages or containers are used for different objects, specific variables belonging to particular types are used to contain a specific type of data. It is common practice to refer to the age of a person as an integer; for instance, when a person mentions his/her age they say a whole number such as 34 or 18 or 65. These fall under the category of integer programmatically. On the other hand, when decimal points are needed to represent something then a float (short form for a floating-point number) is used. For example, data involving weights or other measurements where precise value is important, such as 1.5 or 3.75 etc. fall under a separate category named float.In computational thinking terminology, a variable is a data-holder or a container used to hold data (Figure 3). Typically, the four common data types areInteger, Float, String, and Char. Different exercises have been designed to teach mathematics and computational thinking to students. As mentioned already, these kinds of graphics representations have become an increasingly effective in stimulate students and to convey technical information (Chandramouli, Narayanan & Bertoline, 2014). Enhanced engagement can be attained by actively involving the participant in the process and VR is a proven tool that engages learners effectively. Figure 3 below shows interaction with geometric objects using common I/O (Input/output) devices including touchpad, keyboard, mouse, etc. Furthermore, graphics attributes such as color can be effectively used to enable interactive learning. As can be seen from Figure 4 (below), color is used effectively to categorize these different types.

Figure 3 Interaction Using Common I/O Devices

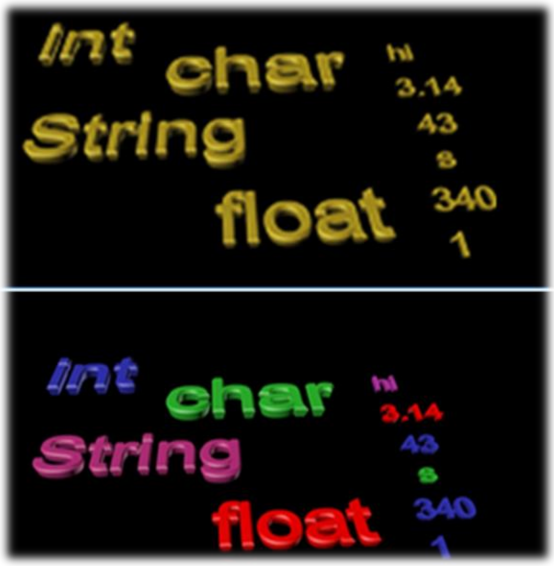

Figure 4 Data/Variable Demo

The steps involved in the process of designing and implementing the framework for the BR-based software are summarized into three major procedures, Figure 3:

1) The 3D models are created using a software (Autodesk 3Ds Max or Maya) and open-source programming languages such as Processing©
2) Subsequently, these are exported to a compatible format such as object format
3) Then they are imported into a platform such as Unity© and customized for specific modes/interfaces.

Similarly, various visual and hands-on examples are used to demonstrate the concepts of functions, iterations, loops, and expressions, all of which are important concepts underlying algebra and programing. The use of non-traditional instructional tools and techniques to simplify pedagogics is widely advocated (Driscoll, 2005; Chandramouli, Jin & Connolly, 2012). This study uses a desktop Virtual Reality based visualization to create virtual representations that facilitate user-interaction. This kind of framework supports active learning methods by incorporating problem-solving and project-based learning (PBL) that enables students to comprehend difficult conceptions by reducing the cognitive overload and by increasing the engagement (Chandramouli, Takahashi, & Bertoline, 2014).

3. Results and Discussion

In this paper, the authors used VR environments in Math and other STEM disciplines to design and deliver interactive exercises. The project analyzed the reduction of gap between classroom learning and real-world implementation using interactive visual examples. With the proposed framework students can learn in an interactive manner using affordable virtual environments. The study also addressed the issue of reducing cognitive overload by minimizing confusing terminology. The use of low-cost VR as a medium for teaching introductory STEM conceptsserved as an effective means to communicate abstract notions. Of late, a well-known and effective method is the use of games and interactive framework that is used to effectively impart computational thinking skills to students (Hernandez, Silva, Segura, Schimiguel, Paradela, & Bezerra, 2010, Papastergiou).The advantages of such display systems for 3D Visualizations include the following:

- the ability to generate and evaluate alternative representations
- navigation in multiple modes (walk, fly, pan, zoom)
- immersion
- intuitive and real-time interaction

Figure 5 demonstrates the use of the interactive visualization to understand practical applications of polynomials. Learning and gaining experience in computational thinking necessarily involves the progress of critical thinking and problem-solving skills. At the end of each section, game-based review and quiz exercises are provided to reinforce the materials learned. The following are some of the drawbacks among existing approaches:

- Using difficult language/structure that is not easily understandable by undergraduate students.
- Not delving deeply into the fundamentals, which makes understanding the advanced topics difficult.
- Not covering the mathematical, geometric, and trigonometric foundations of modeling and animation in sufficient detail.
- Covering too much unnecessary material not required in the introductory stage, resulting in a cognitive overload.
- Improper and inadequate use of images. Carefully designed pictures can greatly stimulate reader's interest and especially in a topic such as modeling, this can be done with custom created models and image.

Figure 5 Interactive Learning of Polynomials and other STEM Concepts

4. Conclusion

Enrolment, retention, and graduation issues are being experienced by many educational institutions in various STEM and other disciplines. To kindle students' curiosity, an interactive platform that can enable a fun-learning setting was offered. Besides serving to boost the math and computational thinking abilities of learners, this study will also add to the advancement of a new instructional model that can assist different educational disciplines especially in Science, Technology, Engineering, and MATH. This research can result in noteworthy effects in the following areas: enhancing STEM curricula by contributing to increased critical thinking skills, generating STEM graduates with superior skills, improving student employability, enhancing mode of instruction, and increasing Student Graduation Success. Despite the tremendous advances made in STEM disciplines in the last few decades, academic institutions are struggling with increasing attrition rates (drop-out) due to the lack of innovative instructional approaches. Interaction and collaboration are key to important academic practices such as active learning (AL), problem solving (PS), critical thinking (CT), and project-based learning

(PBL). These skills are not only unavoidable for academic realization, but are also enormously appreciated in the industry.

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