Golden Material 3D: An Interactive Decimal Numerical System for Children

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Abstract: Several studies highlight difficulties in the teaching of the Mathematics, particularly, the numeral position system. It is common the teachers to adopt concrete materials to aid the teaching of this content. The Golden Material is one of the resources used in the learning of numbers. Nowadays, due to the decreasing cost of computers, Virtual Reality Environments are more accessible. This facilitates the use and creation of applications. This work presents a tool for supporting individuals’ understanding the Hindu-Arabic numeral system taking as base an implementation in virtual reality related to the Golden Material. The work uses free software for visualization and the Virtual Reality Modelling Language – VRML for its construction. This project can contribute individuals’ grasping how to write numbers. However, the Project respects the concrete material experience that is necessary for children according to the cognitive characteristics of each age.

Keywords: Virtual reality, Mathematics Education, Numeric Decimal System

1. Introduction

To understand and write the Hindu-Arabic numerical system is not as simple as it seems, mainly for those who are beginning the studies in formal mathematics [6]. Independent of the group age, individuals have several difficulties for understanding the relationship between the numeral and its positional value, implicating in writing a number such as (325) as follows: 300205 instead of 325.

“In the process of transforming scientific knowledge in school knowledge it is necessary to consider the obstacles involved in the construction of mathematical concepts in a way that one can understand how students learn them. Obstacles are
not presented only in the complexity of the contents, but they are also part of the cognitive, social and cultural conditions of who will learn” [19].

Schools have concrete materials that contribute for the process of teaching-learning the numerical positional system, in our case the Hindu-Arabic. One of these materials is the Montessori or Golden Material that it is the focus of this work. There are already virtual creations of the Golden Material [10] however there are no evidences of some in virtual reality.

Robles (1997) [5] affirms that the use of the Computer science in the education and training should consider many factors. Its simple use is not the solution for the problems, then, to computerize the traditional material is not solution by itself. Bork (1998) [5] complements saying that risk is in confusing the delivery of information with learning, smuggling essential elements, such as resolution of problems, creativity and the instructors and students' imagination. In this context, technologies such as the Virtual Reality (VR) can be an important differential.

The objective of this work is to present “The Golden Material 3D”: an interactive decimal numeral system for children in VR, they can represent numeric amounts. The work aims to contribute for developing learning and teaching mathematics.

In the section 2 we present concrete materials used at schools for teaching mathematics, in section 3 we define virtual reality, the section 4 show the development of the "Golden Material application in Virtual Reality", in the section 5 we demonstrate the partial results, considerations and future directions.

2. Concrete Materials for Teaching of Mathematics

The humanity's history shows us that the number concept and their generalizations are something inherent to the human being that was always capable to recognize the changes in collections such as children or flocks, in the case of an object has been removed or increased [6].

The difficulty in to conceptualize numbers is in the fact that this is a mental construction starting from the relationships that the children do between objects and collections of objects. In agreement with the Piaget’s studies it is “a concept built by the individual, through a process that involves his biological ripening, the lived experiences and the information that it receives from the middle... in the synthesis of the order's relation and hierarchical inclusion” [13] (Figure 1).
The numerical system that is used by us is positional. The counting for grouping the numeral representation is made by the fact that the value of each digit component of the number is different depending on its position.

The Hindu-Arabic numerical system uses only ten symbols (0 1 2 3 4 5 6 7 8 9) to represent an amount. A digit or symbol will have its certain value according to its position in the number. They can be grouped like values and simplify their representation. As example, in the representation of the number $325 = 300 \times 100 + 20 \times 10 + 5 \times 1$ it is used only three digits.

Contributing for understanding numerical’s representation since it is a mental construction it is difficult. Schools have used the abacus, the place value notation and the Golden Material manipulating materials, assuming that they are a preparation for a more solid and efficient learning and intellectual autonomy.

### 2.1 Abacus

The abacus it is an instrument used there are centuries for enumeration and operations. In the abacus each pin represents a position of the decimal numeral. The first pin of the right represents the unit and the subsequent ones represent the dozen, hundred, unit of thousand and so on. Every time that they group ten pieces in a pin should be changed them immediately by a piece to the left, representing a unit of the following order.

### 2.2 Place-Value

The Place-Value is one of the most used didactic materials at Brazilian’s schools and in several countries [10]. This propagation is due at its low cost, easy making, manipulation simplicity and versatility in the work with numbers.

It is made in paper, for teachers and students, starting from horizontal folds and vertical divisions indicating the "houses" of the unit, dozen, hundred and unit of thousand. From the right to the left, the values are represented by sticks, being changed ten sticks by one of the subsequent to the left.
2.3 Montessori Golden Material

The Material Montessori or Golden Material (Figure 2) was idealized by the doctor and Italian educator Maria Montessori for supporting sensorial education. Today the material supports activities that aid the learning of numerical decimal system, methods of making algorithms, study fractions, conceptualize and calculate areas and volumes, decimal numbers and other activities.

With the Golden Material the abstract numerical relations have a concrete representation. For instance, the cube represents a unit, the bar a dozen, the plate a hundred and the big cube a unit of thousand. Each ten cubes are changed by a bar; each ten bars are changed by a plate; each ten plates for a big cube. This way is possible to represent the decimal numerical system and calculate the numbers.

<table>
<thead>
<tr>
<th>Cube</th>
<th>Bar</th>
<th>Plate</th>
<th>Big Cube</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Cube Image]</td>
<td>![Bar Image]</td>
<td>![Plate Image]</td>
<td>![Big Cube Image]</td>
</tr>
</tbody>
</table>

Figure 2. Pieces of the Material Montessori or Gold Material

3. Virtual Reality

3.1 What is Virtual Reality

Kirner (2004) [14] defines VR as an advanced interface technique, in which a user can accomplish immersion, navigation and interaction in a synthetic computer generated three-dimensional environment, using one’s multi-sensorial channels.

The immersion is related to sensory participation and user's attention capture. The interactivity is due to user's communication with the system [17].

Despite of VR exists almost four decades; it has been standing out in the last years. Using VR sophisticated equipments is expensive, however with the progress in technologies and its decreasing costs VR has left to be used just in great companies or research institutions. VR has become affordable to public school institutions and ordinary people. So, individuals can simulate imaginary and real situations and places. This way contributing to develop several curriculum areas and human knowledge [7], [8], [9].
3.2 Virtual Reality as Teaching Resource

Virtual Reality Systems - VRS, can support educators as a learning tool that makes possible students to learn through experimentation, because the student can navigate in the 3D space, hear, see and manipulate objects, as if they were in the real world [14]. Other possibility is the student to use this tool to build his own virtual environment, in the development of multidisciplinary projects [8].

These benefits can be increased by the fact that if one does not have in hands the necessary real material as learning resource or it is impossible to be in a certain place/space, it may keep the learner involvement in the task.

The involvement idea is linked with the degree of motivation for a person's engagement within a certain activity. The involvement can be passive, such as to watch television, or can be activate, like when participating in a game [3].

Brandão (1998) states there are 1st and of 3rd person experiences. In the 1st person experience the individual knows the world through his interaction with it. Knowledge is direct, subjective and frequently unconscious. The individuals live the experience; however they do not have a clear definition that is learning. Such experiences are natural and, usually, private.

When the apprentices hear the report of an experience or they learn starting from the description done by other person it is a 3rd person's experience. This form of learning is objective, conscious and implicit.

As Brandão (1998) states a VRS that allows immersion and individual exploration, they live 1st person's experiences and they explore the information as a daily experience.

Bell; Foglerl (1995), carried out work presenting advantages of using VR techniques on education such as:

(a) Students' motivation based on 1st person's experience;
(b) They might illustrate characteristics and processes better, in relation to other means multimedia;
(c) It allows to the apprentice to redo experiments within atemporal form, diverse from classic classes;
(d) Because it requests interaction, it demands that each participant becomes active inside of a visualization process;
(e) It encourages the creativity, catalyzing the experimentation;
(f) It teaches abilities computations and of domain of outlying.
4. Golden Material in Virtual Reality

4.1 Idealization and execution of the Application

To begin the development of an application for education it is necessary to consider for whom, this one learning styles and skills, besides assuring that this is a need, simple to use and low cost [2]. The application presented on this paper is a tool that is designed to support the work with numbers. It can be used beside the real materials, and it has the attractive of using computers for hands-on manipulation.

The "Golden Material 3D" (Figure 3) uses non-imersive VR technology. It has a positive point that is low cost. However, there is absence of immersion sensation. On the other hand, the tool adds value to learning situations [15].

![Initial interface of the Golden Material 3D](image)

Figure 3. Initial interface of the Golden Material 3D

The application is developed in Virtual Reality Modeling Language - VRML, a scripting language that makes possible to produce web-based 3D virtual environments and simulations at low cost and visualize in any machine.

VRML is a platform independent language that allows the creation of 3D sceneries. In these scenarios one can walk, visualize objects by different angles and interact with them. It is necessary only to write a VRML code using a text editor and, later, a 3D browser, in this case, Cortona 3D. Once edited, the files are recorded in format ASCII with the extension .wrl. The file does not need to be compiled.

In the version 2.0 of VRML, the objects of the virtual world can move and answer to events based on the time or in the user's initiatives. Besides, this version allows the use of objects multimedia, as sounds and films in a 3D scene.

The developed application follows the requirements in [14].

**Interactive.** In that context, the interactive is associated to the user's ability in navigating and manipulating the three-dimensional objects. Manipulation forms can be operations such as Rotation and Translation, to move the objects and to start specific animations.
Use easiness. The application is simple and easy of using; therefore the user does not have as activity end the use of the movable application, but, through her to reach a certain purpose, in this case to set up the numbers (Figure 5).

Content. The application possesses a repository of information to make possible the user a better understanding of the virtual environment. Through three-dimensional representation of objects of the real world the user has a better understanding of its use.

Figure 5. Number 125 mounted in the horizon, being used of the virtual objects

4.2 Observations in Use

We made tests using the application with four students and two teachers. The experiences were carried out by using a netbook.

Two students of Youths and Adults Literacy Education participated have previous knowledge on the concrete Golden Material. The students will be called J.A. (14 years) and L.S. (41 years), a student of third year no literate, L.A. (9 years) and one of the fifth year I.Q. (11 years), the last two had never manipulated the material.

Part 1: Intuitive Navigation

J.A.: "I already saw this, I know the name of this business", referring to the objects of the game. He navigates on the buttons of the software.

L.S.: "It seems a cube, a bar", demonstrating the knowledge on the objects. She navigates rotation and translation with easy localization.

As L.A. as I.Q. were not familiarized with the game and they needed immediate orientations.

Part 2: Driven Navigation

They were requested the representation of some numbers.

L.A.: "How catch it? Does it press on top?" It was oriented how to drag the objects for the horizon which he did correctly, to represent the 16 (sixteen). Then
he made the requested number 102 (one hundred two), he executed correct and quickly the task, without questioning.

L.S.: It was requested the representation of the number 26 (twenty-six), she did question "How like this?" she is being guided to click and to drag, she executed without more orientations the task of representing this and other numbers.

I.Q and L.A., after orientation about the representation of the objects and how to use them got to represent the requested numbers easily.

Questioned on what is good and what would need to improve the game, the students commented: "It is hard to see, the letter is small, I think you have to change the color of the letter" (L.S.); "the screen (the background) it is very dark", "We learn more mathematics" (I.Q.); "It is seem like a day", "It leaves the smartest children", "Can I play again another day?" (L.A.)

Similar the teachers, one teaches Mathematics and the other Sciences commented that the game is very interesting and there is necessity of larger letters with better color contrast.

5. Partial Results, Considerations and Future Projections

After the test with the users was observed:

The fact of using a netbook for the test influenced initially in relation to the attention to the game in itself.

- For the understanding of the objectives of the application

The literate students as well as the no literate ones understand the objective of the application and its use in learning mathematics. Those that already had previous knowledge of the material manipulation did not need orientations on the objects, just of how to use/manipulated them in the game interface, differently from those ones that did not know the material.

- For the Interactive Interface

It was verified the necessity of some changes such as size and contrast of the letters, and a specific place for assembly game results.

And, it is desirable a certain user autonomy. The intention is making the game available in public spaces. So, it will be necessary providing orientations on how to use of the game and present some challenges that motivate its use. For instance, writing numbers resulting of problem solving situations and mathematical challenges.
6. Conclusions

The "Golden Material 3D", is a VR application that provides 1st person experience. It allows active user’s visualization, interaction and participation similar to the ones with the concrete material. As the concrete one, the virtual Golden Material can be produced at low cost. Both can be used side by side at school for supporting interactive teaching and learning real and virtual situations. Hence, stimulate the use of traditional and innovative materials can add value to math teaching and reach diverse individuals’ learning style.

The "Golden Material 3D" encourages creativity and provides communication opportunity with other users in real and virtual spaces if visualized through the Internet.

Finally, the interactivity, easy to use, content significance and its usefulness features can support the "Golden Material 3D" as an interesting tool for using inside and outside the classroom.

References


