Reality in virtual space: micro-worlds for teaching geometry

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Abstract

The purpose of this paper is to analyze how a microworld we have built in SL can help students in building spatial geometry concepts about polyhedra within Papert's constructionist theoretical framework. It is a 3D immersive laboratory with six rooms and interacting objects strategically arranged according to the van Hiele levels. It gives feedback and encourages students' progression through its levels, without emphasis on the assessment tasks being completed. During the school year 2012, second and third year students from two South Brazilian high schools participated in the experiment. Here, we will analyze the interactions of one of these 26 experimental classes according to the van Hiele model of the development of geometric thought.

Keywords: Computer Supported Learning Environments, Educational Technology, Simulations

Extended summary

According to Papert (1980), microworlds can become a context for the construction and toleration of "wrong" (or, rather, "transitional") theories that teach us as much about theory building as true ones but are not tolerated in schools.

Second Life (SL) is a vast simulation of an Earth-like world and a viable and flexible platform for microworlds and simulations (dos Santos, 2012). Once the SL user has logged in and taken on an inworld digital representation in the form of an avatar, she can enjoy the 3D scenery, interact with other avatars, or create objects, which can be made interactive through its *Linden Scripting Language* (dos Santos, 2012).

The van Hiele model (van Hiele, 1985; Burger & Shaughnessy, 1986) distinguishes five levels of thinking in geometry. At visualization level, the student recognizes figures by their appearance, without explicit regard to properties of its components. At analysis level, the students recognize their properties but do not yet order or relate them to each other. At abstraction level, the student orders and deduces properties one from another and can distinguish between the necessary and sufficient properties in determining a concept. At deduction level, the student reasons formally with axioms, definitions, theorems, and an underlying logical system. At the rigor level, the student can compare various geometries and systems based on different axioms even in the absence of concrete models.

According to van Hiele (1985), a student progresses through each level of thought as a result of instruction organized into five phases of learning. In the inquiry phase, the teacher presents the material to the student, who may discover some structure from it. In the directed orientation phase, the teacher chooses the material that will gradually reveals its structure to the student. In the explicitation phase, students learn to express their opinions about the structures using the habitual terms. In the free orientation phase, the subject is for the most part known, and the teacher assigns open-ended tasks. In the integration phase, the student tries to condense the domain into one whole.

In this paper, we analyze how a microworld we have built in SL can help students in building spatial geometry concepts about polyhedra within Papert's constructionist theoretical framework. It is a 3D immersive laboratory with six rooms and interacting objects strategically arranged according to the van Hiele levels. It gives feedback and encourages students' progression through those levels, without emphasis on the assessment tasks being completed.

Figure 1 – Teacher (jairoweber) and student (barney14) beginning the laboratory activity.

In the first room (Figure 1), each solid asks an open question to the avatars, aiming at revealing student's previous concepts. In the second room, some of the solids respond to stimuli with counter-arguments, stimulating the apprentices to carry out clarifications on the concepts of edge, face and vertex. Next we have the Plato room, which explores the Euler's polyhedron formula and the concepts of concave and convex solids and regularity. In the fourth room, eight properties of polyhedra are scattered around a square based pyramid that reveals, every second, its inner right triangle; the student must recognize the existing four true statements, each error implying in having to restart the activity. The fifth room exhibits the construction of a right tetragonal prism; only after correctly answering the last one from a few questions the student will proceed to the next room. The last room covers the concepts of surface, volume of prisms, and pyramids; here, through questions and animations, five solids stimulate the connections among these concepts.

We now proceed to the analysis of relevant excerpts of text chat interactions of one of 26 experimental classes according to the van Hiele model. The participants in this session are the avatars barney14 (student) and jairoweber (teacher).

Figure 2 - Initial student interactions with virtual laboratory (first room)

In the first excerpt (Figure 2), the student apparently had considered vertices instead of edges and two of Van Hiele learning phases are apparent. Firstly, the teacher inquired the student about the choice he had made, without correcting his (wrong) understanding of edges as "meeting of vertices"; then, the teacher directed the student while he reworks his option and correctly counts the edges. Notice that the contradiction between the student's visualization and his response was essential for his subsequent advance in the concept of edge. The octahedron exhibited three spheres around it with the numbers 8, 6 and 12; only if the student touched them in the correct sequence of the number of faces, vertices and edges, without any further explanation about these concepts, another solid would be started.

Figure 3 - Student interactions with the laboratory's second room

In the above dialog (Figure 3), the hexahedron showed what made it convex and asked barney14 to find a concave object. It took him four minutes, but the student chose it correctly. When the object asked him to write about the concept of concave, however, he found it difficult. barney14 answered correctly about Euler's polyhedron formula, but needed to reflect further on it. The teacher returned to the strong points of visualization and guided barney14's steps towards the concept of concave.

Figure 4 - Initial student interactions with the laboratory's Plato room (third room)

Observe, in Figure 4, that barney14 correctly identified vertices, edges and faces. He confirmed their numbers and found one of its properties by means of the Euler's polyhedron formula. This excerpt suggests that barney14 still was at the visualization level because he had not recognized the properties of polyhedra, but within this level he was advancing to the explicitation phase as he was able to make some relationships like this one between Euler's formula and concave objects.

Figure 5 - Further student interactions with the laboratory's Plato room (third room)

In this last excerpt from the dialog (Figure 5), barney14 made a connection with the previous activity with the icosahedron to obtain the correct number of edges. He also accurately calculated the number of vertices through Euler's formula. Therefore, we can infer that he was able to articulate about a few geometric concepts and that he has moved to the explicitation phase. Notice also that barney14 mentioned some elements of the octahedron; from that we can assume that he began to recognize properties in polyhedra that went beyond the visualization and that he, therefore, was entering into the analysis level.

Being short of space, the present article had to limit itself to student progress until the third room only. From the above analysis, however, we consider that the interactions between objects and avatars were essential for reflections on the concepts involved in the constructing a polyhedron. Therefore, we believe that the immersion in this virtual lab built in Second Life can provide engaging learning situations for the development of the geometric thought of the students.

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