Teaching and learning process of spatial geometry using augmented reality.

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Abstract. This study presents results of the research about teaching and learning process using multidimensional visualization (MV) for aid student in special geometry courses. The research was applied in a group of high school students during an information technology seminar. In this situation geometric solids were developed in a workshop about MV. Students were challenged in the production of geometric solids using technology tools based on augmented reality (AR) and the feed back (through a semistructured questionnaire) was annotated in specific forms that allowed the analysis of the results. Like a result, it was found that the use of augmented reality increases the interaction between student, teacher and content. In this way the class was more interesting and thought provoking. Had freedom of creation and a good environment which made learning easier.

Key words: Multidimensional visualization, spatial geometry, learning objets

1. Introduction

Information and Communication Technologies - ICT are increasingly present in our lives, schools and universities. It has contributed to the modification of the way people relate and build knowledge, since they provide multiple dispositions for the intervention of the interacting agent (PRIMO, 2002).

ICT is enhanced through software and multimedia applications developed for the internet, bringing to the classroom many possibilities, such as better-quality teaching and learning processes. Education can be treated as a process of discovery, observation, exploration and construction of knowledge.

In the teaching and learning processes of the mathematics course, it was found that students demonstrate learning difficulty about Spatial Geometry, according to Hoffer (1981), the teaching of spatial geometry presents deficiencies. This happens because teachers usually present the content only in traditional chalkboard and chalk. Thus, flat representations are used to represent three-dimensional solids, making it difficult to visualize and understand.

To improve the process of observation of geometric solids, we applied the Augmented Reality - AR as a complementary tool to construct solids to assist students in the visualization and interaction with the learning objects developed.

This study had as objective to verify how the AR can help in student's visualization and interaction during the development of Spatial Geometry learning objects.

It has been observed that through geometric solids developed in Augmented Reality, the educator is better able to demonstrate situations that are difficult to understand in two dimensions.

The student then feels motivated with the possibility of easily understanding the subject presented.

In the planning and development of solids was used the ADDIE (Analysis, Design, Development, Implementation and Evaluation) model of instructional design. The geometric solids were developed with Autodesk 3ds Max animation software and rendered in AR through the software Aumentaty Author.

This article is structured as follows: section 1 presented the introduction; Section 2 discusses works related to Spatial Geometry in Augmented Reality; Section 3 presents the concepts of Augmented Reality; Section 4 presents the conceptual concept map; Section 5 presents the ADDIE Model of instructional design; Section 6 presents the methodology and development, describing techniques and methods used; section 7 presents the analysis of the results together with the techniques used, and finally, section 8 discusses some final considerations about the work done.

2. Related studies

AR has been used in several knowledge areas as a tool to aid the teaching-learning process, such as in Mathematics and Physics (Forte 2009).

Oliveira and Kirner (2010) in their technical report "Exploring Spatial Geometry in Virtual Reality Environments and Augmented Reality with the use of the AR-Educational Tool" present the Virtual Reality and Augmented Reality as support tools for the generation of virtual solids, manipulated through AR-Educational and visualized through the Internet Explorer browser and through the AR Tool Kit software.

One application example of learning object developed in Augmented Reality (AR) was presented by Nunes, Mühlbeier and Costa (2014), in their article "A Beyblade in Augmented Reality: its pedagogical potentialities in the teaching of spatial geometry", the subject was addressed using the pedagogical support of instructional design model (ADDIE).

According to Sakaguti (2004), conceptual maps are considered as an auxiliary tool in teaching and learning processes, but teachers should not have it as the only teaching tool they need explore all possibilities.

Conceptual map, developed by Joseph Novak (1977), is a tool for organizing and representing knowledge. It is used as a language for describing and communicating concepts and its relationship. It was originally developed to support Significant Learning (AUSUBEL, 1968). It has several practical utilities, highlighting the evaluation of a knowledge acquired by the student.

Virtual Reality (VR) and Augmented Reality (AR) are two areas related to the new user interface generations, which facilitate and enhance user interactions with applications (KIRNER and SISCOUTTO, 2007).

Augmented reality was originated from virtual reality. they have important aspects in common, such as: interactivity (important for teaching and learning processes), 3D graphics and visualization of images in computer equipment.

> Augmented Reality (AR) is a variation of virtual environments (VA), or Virtual Reality, as it is commonly called. VA technologies completely immerse the user in a synthetic environment. While immersed, the user can not see the real world around them. In contrast, AR allows the user to see the real world with overlapping or composite virtual objects. Therefore, AR supplements reality, rather than replacing it completely (AZUMA, 1997, p.2).

Virtual reality favors the formation of an artificial environment in which it is possible to interact with this three-dimensional universe. The VR must be seen as another reality and in it the user will be within the interface. But with Augmented Reality the 3D effects that enter our world (BILLINGHURST and KATO, 1999; BENFORD at al, 1998; KIRNER, 2004).

The visualization of a geometric solid with many sides is difficult. AR brings the advantage that a solid with any number of sides can be viewed in real time and in three dimensions quickly. It Facilitates the teaching and learning processes. The use of AR makes it possible to create elements for use in various research and study areas (KIRNER, 2004). Acoording Filatro (2008), the instructional design is structured in a teaching and learning planning system in different stages. This division is in phases and also known as ADDIE (Analysis, Design, Development, Implementation and Evaluation) model.

Among the instructional design models, one of the most frequently used models is the ADDIE (BROWM and GREEN, 2011). This model incorporates the theories inherited from ID in order to systematize the steps, based on the input, output and process data that occur during learning (JONASSEN, TESSMER and HANNUM, 1999).

In this method it is necessary to understand what are the needs of the public, where as a result of this, the difficulties in spatial geometry were obtained. In the design phase, the objectives of learning, evaluation tools, exercises, content, the subject is analyzed and the workshop is planned. Learning objectives, assessment tools, exercises, content, subject and workshops are developed at the design stage, in the development phase comprises the production and adaptation of digital resources and materials and in the implementation phase the process provides results and discussions.

At this stage the design proposal is applied through a workshop with the purpose of evaluating if the Augmented Reality can offer contributions to the teaching and learning of Space Geometry. In the last phase, the evaluation, result considerations about the effectiveness of the proposed solution. For this, a semi-structured questionnaire was applied to the students to collect data and evaluate the results after the workshop.

3. Methodology

The tests were applied during a workshop at the Information Technology Seminar event. In this situation were developed composite geometric solids through the Autodesk 3ds Max tool and after rendering and visualized in AR through the software Aumentaty Author, following the step of Implementation of the ADDIE model.

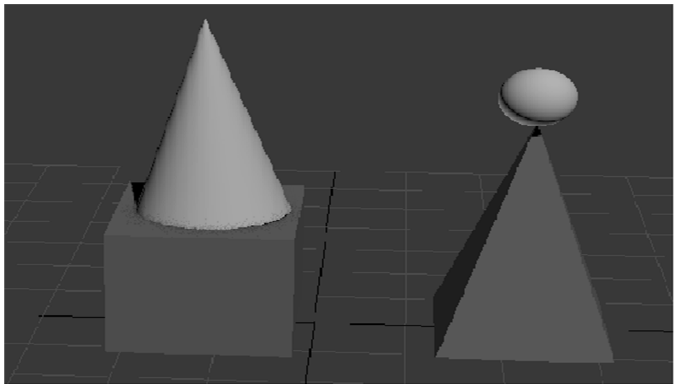

Figure 1. Solids developed by the student1

The ADDIE method was applied in the development of geometric solids using AR. The method was applied in a class of first, second and third year students from the Technical Course on Integrated Computer Science at the Federal Institute - Farroupilha, Campus Júlio de Castilhos, state of Rio Grande do Sul, Brazil. The group of students tested had previous knowledge about the content of Spatial Geometry.

For identification were assigned numbers to the students avoiding the registration of their real names, this way you have then the identification student 1, student 2, etc. As shown in figure 1 and figure 2.

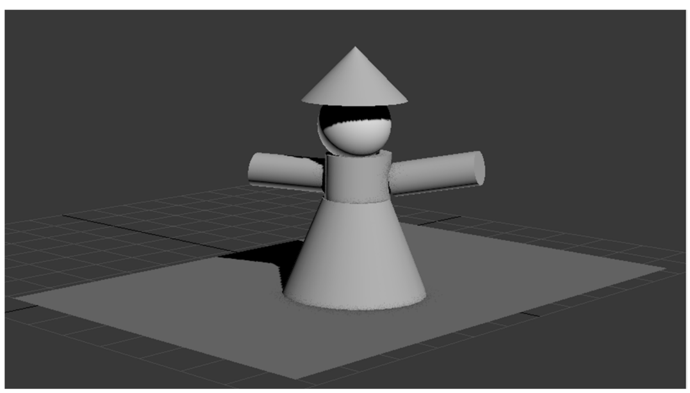

Figure 2. Solid developed by the student2

In the process of instructing students were used accessories such as webcam, laptop, multimedia projector and screen. It was observed that, the Augmented Reality allowed the students better visualization, knowledge and possibility of interaction with the geometric solids. The challenge posed to students was to construct objects composed of geometric solids. To this end, the students tested had full freedom of creation in the formats, colors and sizes. Data for the analysis were collected through a questionnaire composed of semistructured questions. During the analysis, the conceptual maps of each student were compared with the standard map.

> [...] the researchers used idealized conceptual maps, elaborated by specialists and specific subjects, comparing them with the maps elaborated by the students at various moments of the school learning process (FARIA, 1995, p.2).

The standard conceptual map as shown in figure 3, was served as the basis for the evaluation of the questionnaires. One can with this analysis, verify exactly which cognitive Links were reached by the student.

In the standard conceptual map there are links between concepts. Link 1 relates the concept of Teaching Spatial Geometry to the visualization of geometric solids; Link 2 relates to visualization of the geometric solids using the Information and Communication Technologies - ICT and the ADDIE model; Link 3 relates the ICT and ADDIE model with the use of 3ds Max software; Link 4 relates 3ds Max software to the creation of composite solids; and finally Link 5 relates solid compounds presented in Augmented Reality.

Nunes (2006) establishes that Cognitive Link is the relation existing between the subsumers of a conceptual map with sufficient potential to infer directly in the cognitive structure of the individual.

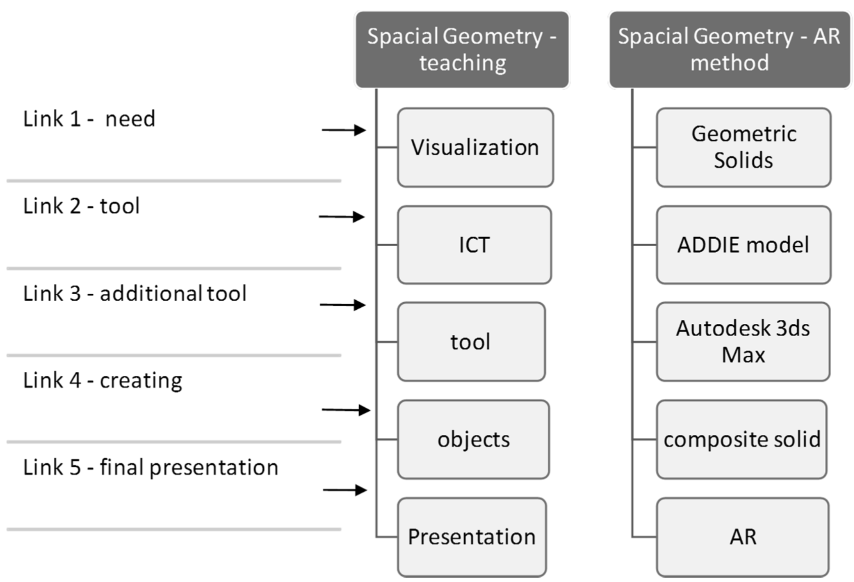

Figure 3. Standard conceptual map.

4. Findings and Discussion

The conceptual maps of the sixteen students were analyzed individually, the analysis was based on the answers of each questionnaire, Figure 4 shows the classifications established as "Weak", "Medium" or "Strong" for each of the Links. Student maps are available at https://files.acrobat.com/a/preview/faa4594b-6e5f-434b-b7e0-41886e4344b2, along with each student's questionnaire responses.

The conceptual maps created by sixteen students were individually analyzed. The analysis was based on the answers of each questionnaire.

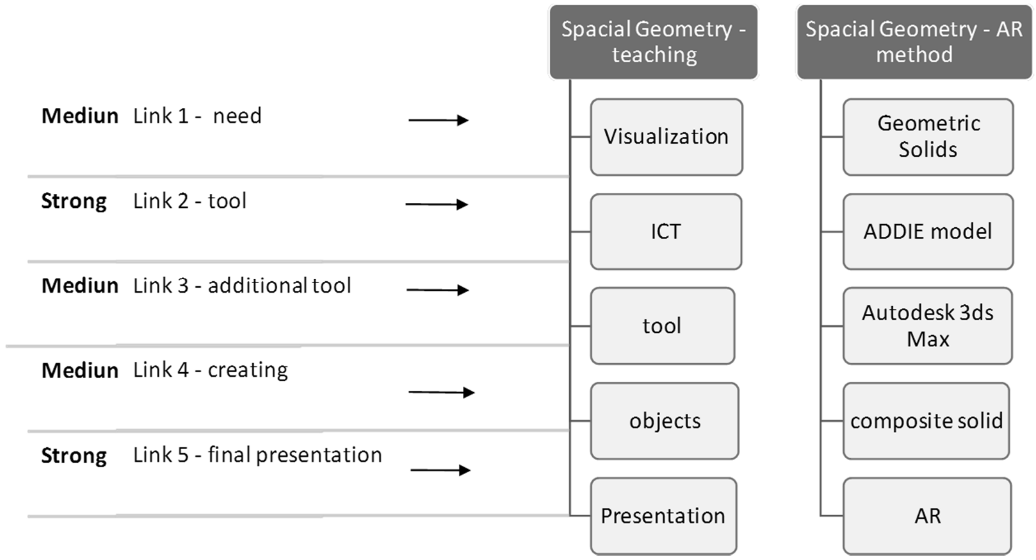

Figure 4. Student 1 - conceptual map.

Figure 4 shows the classifications established for each of the Links. Student maps are available at https://files.acrobat.com/a/preview/faa4594b-6e5f-434b-b7e0-41886e4344b2, along with each student's questionnaire responses.

The Link was classified as "weak" where the student did not convincingly articulate their concepts; "medium" where the concepts were articulated, but without a good degree of deepening, and, finally, the concepts articulated in an appropriate way were classified as "Strong".

Table 1. Links and their respective questions.

Link	Question
1	7, 8 e 9
2	10
3	1, 2 e 3
4	4, 5 e 6
5	8

The questions are set out in the Links according to concept map. Table 2 is presented with the Links classification of each student.

The questions are set out in the Links according to the concept of the concept map. Table 3 is presented with the LINKS classification of each student. For better understanding, the student's answers are analyzed as follows: LINK 1 appears with a score of "Medium" because it refers to the average of the answers from question 7 (Strong) "to 8 (Weak)" and 9 (Strong); LINK 2 is "Strong" because the answer to question 10 was evaluated as "Strong"; LINK 3 was "Medium" because the answer from question 1 (Weak) to 2 (Weak) and 3 (Strong) "; the LINK 4 Medium, because the answer from question 4 is (Strong), 5 (Strong) and 6 (Weak); LINK 5 is "Strong" because the answer to question 8 was (Strong).

Briefly, the links analyzed are strong only if all answers are strong. Links are weak if all responses are weak and for the other response combinations Links are classified as medium. Table 2 presents the Links interpretation.

Table 2. Links Interpretation.

Link	CONCEPT
Link 1	The teaching of Spatial Geometry needs visualization of the geometric solids.
Link 2	It is possible to visualize the geometric solids using the Information and Communication Technologies - ICT with the support of the ADDIE model.
Link 3	The ADDIE model is used to guide the construction of geometric solids through Information and Communication Technologies, such as Autodesk 3ds Max.
Link 4	Compound solids can be developed with 3ds Max software;
Link 5	Compound solids can be presented in Augmented Reality.

Table 3. Classification of cognitive Links for each student.

Student	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5
Student 1	Medium	Strong	Medium	Medium	Strong
Student 2	Strong	Strong	Medium	Medium	Weak
Student 3	Strong	Strong	Medium	Medium	Strong
Student 4	Strong	Strong	Medium	Medium	Medium
Student 5	Weak	Weak	Weak	Medium	Strong
Student 6	Strong	Strong	Medium	Medium	Weak
Student 7	Strong	Strong	Medium	Medium	Strong
Student 8	Strong	Strong	Strong	Medium	Strong
Student 9	Medium	Strong	Medium	Medium	Strong
Student 10	Strong	Strong	Medium	Medium	Medium
Student 11	Medium	Weak	Medium	Medium	Strong
Student 12	Strong	Weak	Strong	Strong	Strong
Student 13	Strong	Weak	Medium	Strong	Strong
Student 14	Strong	Strong	Medium	Strong	Strong
Student 15	Medium	Strong	Medium	Medium	Strong
Student 16	Medium	Weak	Medium	Weak	Strong

The Links interpretation of each student, only the classification "Forte" was considered, becouse it reflects the student's best understanding of Link.

As an example, Student 1 has a better understanding of LINK 2, where he was able to visualize the geometric solids using the ICT with the support of the ADDIE model and LINK 5, in which the compound solids were represented in Augmented Reality .

Student 2 was classified as "Strong" in LINK 1, where he approves that the teaching of Spatial Geometry needs visualization of the geometric solids and in LINK 2 where he was able to visualize the geometric solids using the ICT with the ADDIE model support. Then the cognitive Links of all 16 students were evaluated.

Table 2 shows Links 1, 2 and 5 presented the highest number of "Strong" classifications, which indicates through their interpretations that the visualization is an important element for the teaching and learning processes. learning with the use of ICT in the construction of geometric solids in AR.

Through these evaluations, it is verified that the objective of this work to use the Augmented Reality as a tool for visualization and interaction in the teaching and learning processes of the spatial geometry content was achieved.

It can also be inferred that the ADDIE model was effective for the planning and development of the geometric solids because they provided good visualization and interaction.

8. Conclusion

The proposed Augmented Reality representation aimed at providing the tested students with a form of interaction and three-dimensional visualization of the geometric solids. With this application and according to the questionnaire answered, they were able to easily visualize the solids developed during the workshop.

The tested students considered the method and tools useful and easy to use. Augmented reality provided the opportunity for efficient and easy visualization and all this improved understanding of spatial geometry.

It was found that the use of augmented reality increased the interaction between student, teacher and content. In this way the class was more interesting and thought provoking. Students tested had freedom of creation.

Finally, the results show that the augmented reality can positively influence the learning of spatial geometry and can create a more productive and interesting environment where the student studies and develops his creativity while applying the fundamental concepts.

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