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VISUALIZATION IN THE TEACHING OF GEOMETRY FOR CIVIL ENGINEERING STUDENTS

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Abstract –*The teaching of Geometry is basic for the study of Civil Engineering. The author considers that one of the difficulties that arises among the students of this subject is the lack of visualization. A survey was conducted among students of the second semester of civil engineering, and among Geometry professors at different universities in the city of Guayaquil, to confirm or not this idea. Visualization was confirmed as one of the main causes of difficulty in the study of this subject. It was also observed that students and professors consider the use of Information and Communication Technologies, ICT, to be of great importance in the class dictation, and that the lack of knowledge of basic mathematics reviewed during high school is another important difficulty in the teaching-learning process of Geometry. The article ends with the proposal of a system with interdependent elements, which serve as support for the student and the professor during the development of the course.*

Key Words: Visualization, geometry, survey, teaching, learning, mathematics.

1. INTRODUCTION

A good knowledge of Geometry is basic for the development of the Civil Engineering career, both at the level of graduate and postgraduate studies, as well as in professional practice. This statement is based on the analysis of the different specialization subjects, such as Structures, Hydraulics, Geotechnics, among others, whose content requires an unquestionable spatial approach.

Faced with this reality, which is evident for Geometry and is also shared with various basic subjects of the Civil Engineering career, it is necessary to reinforce its teaching-learning process, focusing on the main weaknesses and proposing a solution.

An important reference in the teaching of Geometry is presented by Dina Van Hiele-Geldof and Pierre Van Hiele, a Dutch couple who in 1957 presented a model of Geometry teaching to the scientific community, in which they point out that the learning of Geometry occurs through 5 levels of thinking. The existence of scientific articles and books that mention these authors attest to their validity today.

The first level within the Van Hiele model is that of visualization. This article aims to demonstrate the validity of the statement that visualization is the starting point for the teaching-learning process of Geometry, and propose solutions to achieve it.

2. WHAT IS VISUALIZATION?

Different authors have defined visualization. The act of "visualizing" can be seen as a simple synonym for "seeing", or it can be broken down in more detail. Some of these breakdowns are:

- Gatica (2012): visualization "operates with the functioning of cognitive structures, the relationships between the various representations of a mathematical object, and also intervenes in a certain culture" ... "when we refer to visualizing a concept, we are talking about understanding a concept through a visual image" (p.92).

- García and López (2008) affirm that visualization is "an activity of reasoning or cognitive process based on the use of visual or spatial elements, both mental and physical, used to solve problems or prove properties" (p. 48).

- Clemens and Battista (1992) state that "Basic for spatial intelligence are the abilities to perceive the visual world accurately, to carry out transformations and modifications on one's initial perceptions, and to be able to re-create aspects of one's own visual experience" (p.444).

All of the above criteria are useful for this document. The cognitive structures and the various representations of a mathematical object that Gatica mentions are elements that intervene in the learning of geometry, since geometric figures present mathematical relationships between their characteristics, and their analysis generates an advance within cognitive structures. This is linked to the statement by García and López, who also mention the cognitive process as part of visualization. That is, all the authors mentioned consider visualization as an instrument or a path within the process of cognitive advancement. Likewise, García and López's reference to problem solving and the demonstration of properties fits with the representations of the mathematical object that Gatica underlines. These properties are the same ones on which the transformations and modifications that, in the advance in spatial intelligence, will be produced according to Clemens and Battista. The author considers that these statements are valid, and allow progress

in the construction of a proposal for the improvement of the spatial visualization of a student, based on a clear definition of this concept.

However, the author considers that Arcavi's (2003) definition for visualization is the one that comes closest to the research development carried out. This definition indicates:

"Visualization is the ability, the process and the product of creation, interpretation, use of and reflection upon pictures, images, diagrams, in our minds, on paper or with technological tools, with the purpose of depicting and communicating information, thinking about and developing previously unknown ideas and advancing understandings". (Arcavi, 2003, p. 217).

In this sense, the term "visualize" will be used, since it does not only speak of an action (see), but it encompasses both the ability to carry out the action and its process and product. This point is consistent with Van Hiele's initial level of thought within the Geometry teaching model, since it is precisely the process of "interpretation" on "figures, images and diagrams" that allows the student to "develop ideas". Arcavi's definition concludes with "advancing understandings", which is consistent with the Van Hiele model, since visualization is only the first level of thought required for learning Geometry.

3. CASE STUDY

In order to substantiate the assertion that visualization is the starting point for the teaching of Geometry, and that this lack of visualization slows down the learning of basic concepts in this subject, two surveys were performed:

- - to university students of the Civil Engineering career
- - Geometry professors in the Civil Engineering career.

The first survey was carried out in a group of 48 students who were in the second semester of the Civil Engineering career at the Catholic University of Santiago de Guayaquil. At the date of application of the instrument, the subject corresponded to the first semester. Among the members of the group, 29 had already approved the course, and 19 were taking it, whether for the first or second enrollment.

In order to characterize the Geometry course, it is worth mentioning that between 2005 and 2016, 44 courses had been opened, with a total of 4 professors and 1,253 students, including repetitions of enrollment. The failure averages of the four professors were:

- 61,63% - 20 courses
- 30,00% - 1 course
- 54,74% - 21 courses
- 39,22% - 2 course

The high level of failure stresses the importance of a proposal for the improvement of the teaching-learning process of Geometry. In this sense, the applied instrument did not focus solely on visualization, but rather presented some open questions in order to determine other causes.

The professor survey was conducted with 6 university professors who, at the date of application of the instrument, were in charge of all the Geometry courses in the 5 universities that taught the Civil Engineering career in Guayaquil and areas of influence. That is, the survey was not done with a sample, but with the population of the study group.

4. RESULTS

The responses from students and professors point out that visualization is not the only difficulty within the teaching-learning process of Geometry, but it is an important one, which must be addressed. This is evidenced not only because 8.3% of students indicate that the lack of visualization of the content of the subject prevented them from having a good performance in it, but also because:

- 38.1% of students found the units related to polyhedra, circles and descriptive geometry conflicting, because they could not visualize the topic.
- 60.4% of the students think that Information and Communication Technologies, ICT, would make it easier for them to understand the subject. Among them, 58.2% of students consider that ICT would help them to visualize better.
- 82.6% of the students affirm that, with more time to develop competences of visualization of geometric figures, the subject would be better understood.

Other responses that emerged from the survey with the students were:

- The students accept that their knowledge obtained during high school studies helped them to be successful or not in the Geometry course.
- The students understand that from their success in the basic level will partly depend their success in the rest of the career.
- The students want a little more individual attention to their learning needs.
- The students consider that the use of ICT is important in the teaching-learning process of Geometry.

- The students consider that new resources should be provided to the professor for the dictation of the class.

- There are external factors that prevent them from studying productively.

From the survey Geometry professors, the main responses were:

- In an open question about the topics that should be included in a professor training course based on ICT, to improve the dictation of the class, the most repeated answer was in the sense of improving the visualization skills of the students.

- Professors consider that the initial skills required to be successful in the Geometry course are Basic Mathematics and Technical Drawing.

- All professors consider that the lack of knowledge prior to the Geometry course is one of the reasons why the student does not achieve the learning objectives of the course. Other causes are the lack of spatial visualization, the little dedication of the student, the number of students in the classroom and the forms of evaluation.

- All professors use ICT to dictate the course, both in the form of classroom resources, and in assignments sent to students.

- Trigonometry and Space Geometry are the units that cause the most difficulties for students. One of the causes is the lack of spatial visualization.

- The application exercises would help the teaching - learning process.

5. ANALYSIS OF RESULTS

It is observed both by students and professors, that visualization is one of the most important factors that prevent them from succeeding in the teaching-learning process of Geometry. There are parallels in some responses that underscore this assertion, including:

- Both groups consider that the learning of spatial elements is the most difficult one.

- ICT help to better visualize the topics of the subject.

This coincidence suggests that the initial statement in this document is correct. However, it is necessary to analyze other coincidences regarding the factors that hinder the learning of Geometry, mainly:

- Knowledge of the subjects of pre-university levels, that is, high school subjects like Mathematics and Technical Drawing.

- The importance of ICT in the teaching-learning process of Geometry.

- There are student factors that prevent them from being successful in the Geometry course.

6. CONCLUSIONS

From the results of the surveys carried out, the students' factors that prevent them from dedicating themselves to study stand out. These factors cannot be analyzed within this scientific article and the author's position is that their solution must take place from internal instances of the universities, such as the pedagogical support and student welfare departments, in which support is provided to the students when difficulties arise from environments outside the university.

In order to attend to the other responses, it is useful to generate an integrating proposal, whose elements, when working interdependently, produce a result that is greater than the sum of each of its independent results. Given the importance of ICT, which was mentioned by professors and students through the measurement instrument, and which is explained from the nature of the student as a digital native, it is imperative that the proposal includes them.

The author's position is that this proposal should be focused in the following way:

- The lack of previous knowledge, mainly Basic Mathematics, must be determined from the beginning of the course. Hence the importance of an initial diagnostic test, which determines the need that students have for a support system for their particular deficiencies.

- The particular deficiencies must be addressed through a help system, which could well take the form of tutorials. Online tutorials, guided by professors or by students of higher courses, can solve the deficiencies in high school subjects.

- The students mention that they would like to have more personalized attention to their needs. Since the professor does not have a space to provide that attention, a tutorial can also be provided to all the students who require personal support during the dictation of the subject. This tutoring must not be binding to the grades of the course. It must also be provided online, with the use of ICT, and must be supervised by the professor.

- The lack of visualization must be addressed through an ICT that serves as an instrument for support tutoring and for the student's autonomous study hours. One option is an e-book, designed specifically for the course syllabus, and hyperlinked to detailed two-dimensional and three-dimensional graphics.

- Even though they have not been mentioned in this document, rubrics are an essential instrument for a proposal to support the learning of Geometry, since they allow the professor to detect the main shortcomings and propose solutions, while measuring the evolution of the group's learning.

A support system, designed with these characteristics, can continuously provide feedback from each of its elements. Thus, in each new course, there would be new elements that would improve its functionality. The author's position is that this proposal should be presented to experts, in order to be validated before its application.

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