Cube Test to Measure Whether Qubism 3D Modeling Technology Develops Spatial Visualization in the Study of Orthogonal Projections

C. Helena Chivai, A.A. Soares, P. Catarino

Abstract— In Mozambique teachers still teach in a traditional way without the aid of technological resources such as computers, data show and much less the cell phone, which hinders the implementation of new technological methodologies that can facilitate the spatial visualization (SV) and the recognition of the graphical representations of orthogonal projections (OP) of a given object. The aim of the research is to use the Cube Test (CT) to assess the learning of students subjected to a teaching-learning process based on the use of the digital technology Qubism 3D Modeling (Q3DM) adapted for smartphone, in order to facilitate SV in students of the General Secondary Education of Mozambique. The teaching methodology is based on the following: students solve 2D exercises on paper before mentally visualizing the same exercises in 3D. In this context the research makes use of the CT to assess whether the Q3DM actually enables the development of 3D SV, that is, whether it develops in students the ability to mentally visualize in 3D before the process of moving to 2D space. This is a case study, in a quantitative approach, the topic researched was OP, in a 9th grade general secondary school class, the digital technology used to develop SV was the Q3DM adapted for smartphone because it is free and simple to use. The instruments used were OP exercises using the Q3DM and SV exercises containing three CTs of different levels (simple, medium and complex) to assess whether there was a development of SV. As results, the research showed that the use of the didactic support tool, Q3DM adapted for smartphone, in the classroom can facilitate learning, but does not replace the role of the teacher in the teaching-learning process, because the teacher is still the one who plans, mediates and develops teaching situations based on the knowledge he has about the desired content.

Index Terms— Cube test, 3D spatial visualization, Orthogonal projections.

1 INTRODUCTION

Mozambique has been facing challenges in engineering education since its independence in 1975. The subject of OPs in the discipline of technical drawing, is an obstacle for the students of general secondary education in Mozambique, because the students face difficulties in 2D representation because they demonstrate inability of 3D SV. The literature shows data that prove, in this context, the existence of some difficulties faced by the student, such as the inability to correctly identify geometric shapes based on their formal definition [1], [2], [3], [4], [5], [6]. These students when they proceed to solve the exercises in the two-dimensional plane are unable to solve them correctly because they first perform them on paper before mentally visualizing the same exercise in 3D. In this context the research brings the CT to clarify if indeed technology can develop 3D SV so that students can mentally visualize in 3D before the process of moving to 2D space. The new strategies of integrating information and communication technologies in teaching technical drawing allow an improvement in the perception of SV which is the basis for studying OP, so some researchers suggest that the spatial ability can be acquired with the help of the appropriate environments with access to technology [2].

The reasoning associated with the views of solids is linked to SV, so the study brings the Q3DM technology to simulate solids so that students can manipulate the views to visualize the abstract parts of solids and develop SV, hence the research question arises:

Does Q3DM technology enable the development of spatial visualization in the study of orthogonal projections?

1.1 Spatial Visualization

SV is the mental ability to fix an image of an object, model it spatially to obtain all the details of that object. CT is also the process of mentally recognizing and manipulating the spatial nature of objects and the spatial relationships between objects [3].

1.2 Orthogonal Projections

The OP of an object is equal to its shadow proejected in a plane ~~of projection~~ with a perpendicular beam of light to the desired view. It can be based on a process by which lines are drawn, starting from the observer, and passing through the vertices of an object, to a surface called the projection plane [4]. Its importance in real-world application is, for example, in the graphical representation of cars, appliances, clothing, bridges, houses, urban planning of a city and much more.

1.3 Qubism 3D Modelig

The Q3DM digital technology is a free application adapted for the cell phone that takes up little space. This application features several tools that allow you to build, with blocks, the solid in 3D, simple to manipulate and interactive. It allows coloring, stretching, and shortening the blocks built. Q3DM is allied to the OP because it allows the student to simulate the views of the solids to understand the abstract parts that make 3D SV difficult, (see fig. 1).

Fig. 1. Qubism 3D Modelinga adapted for Mobile.

2 Test of Spatial Visualization

Spatial visualization tests are traditional psychometric spatial ability tests that involve general domain stimuli, have relational to engineering tasks [5]. Generally, the goal is to look for the ability to record in the mind the visual shapes of solids in all projections.

2.1 Cube Test

The CT is applied to the SV, with the goal of measuring the ability to mentally manipulate complex three-dimensional figures. The complexity starts from the perception of unfolding the cube in 2D so that the same cube can be assembled in 3D, this process imposes the representation of mentally rotating the solids quickly and accurately in various positions and is accompanied by optional questions. The example in fig. 2 shows three folded cubes where each cube has five questions A, B, C, D, E of which the correct answer logically takes the form of the pattern assembled in 3D [6].

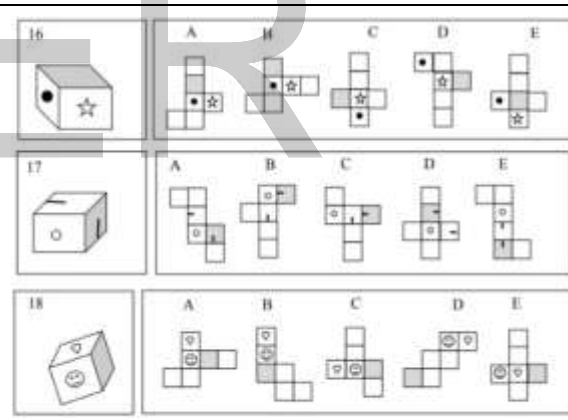

Fig. 2. Three exercises of the Cudo Test.

3 Methods

The methodology used was a quasi-experimental case study, it was so called because it did not contemplate all the characteristics of a true experiment, as complete experimental control was not always possible [7]. The data were analyzed in a quantitative approach and the study was conducted in a public school of general education in southern Mozambique, 24 students of the 9th grade were involved, the average age was equal to 15 years old and one teacher. The instruments used were the observations, and implementation of the Q3DM technology for the SV of 3D solids in the study of OP and the Spatial Visualization CT test to predict the 3D visual performance of students. The research was conducted in three moments, in the first the students had a lesson on OP of two-dimensional and three-dimensional solids. At the beginning of the lesson the teacher explained what OP are, their usefulness and importance. In the second moment, the teacher presented the Q3DM technology to enhance the students' 3D SV of the solids, the students had the opportunity to manipulate this computational resource adapted for the cell phone. It was an interactive class because students showed interest in simulating the various tools of the Q3DM, exercising the OP views, (see fig. 3).

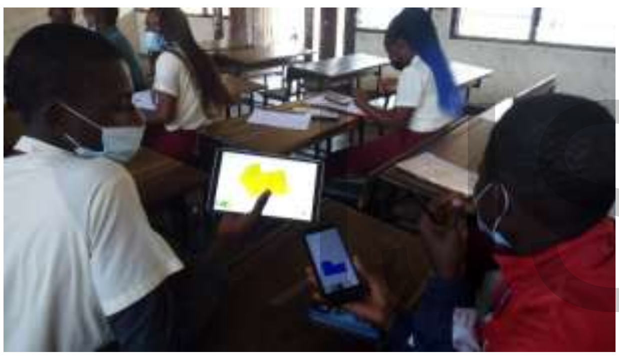

Fig. 3. Students simulating in Qubism 3D Modeling adapted for mobile phones in the study of Orthogonal Projections.

The third moment of the research was reserved for testing SV. First the teacher showed the students three objects with different characteristics, but all with the same rectangular shape. The first red object was simple and flat, (see fig. 4).

Fig. 4. Front view of the flat figure.

The purpose of the object selection was to explain to the students that the plane figure had only two dimensions, widht and length, and that, the observer in its front view obtains a rectangular-shaped geometric figure, consequently for the other views it would be a line because it had no height.

For the second object the teacher exposed a book with the objective of showing the difference between an object with two dimensions and a three-dimensional object that has three dimensions, being length, width, and height, (see fig. 5).

Fig. 5. Front view of the Book.

The last object presented by the teacher is more complex, for being three-dimensional and with relief. This complex object clarified to the students the purpose and importance of OPs in project planning because it has several details and relief, (see fig. 6).

Fig. 6. Complex figure with relief.

After the presentation of the characteristics of the three objects, the teacher then displayed an unfolded white cube with no pattern (see fig. 7).

Fig. 7. Unfolded Cube Exhibit.

The teacher explained to the students that if logical or abstract figure information was applied to the simple unfolded cube without any pattern it would become complex. And that the purpose of the complexity was for the students to understand the SV of geometric figures, (see fig. 8).

Fig. 8. Display of the Cube unfolded with geometric figures.

After the explanation of the unfolded cube was done, the teacher assembled the cube by folding it. In several positions the teacher switched the position of the geometric figures and asked what the information of each visualization plane was, to make sure that the students understood the logic of SV, (see fig. 9).

Fig. 9. Display of the Folded Cube with figures.

To test VE the students were subjected to three different level CTs (simple, medium, and complex) to assess whether there was spatial reasoning when they simulated the Q3DM to visualize the OP views. For the simple level CT the unfolded cube featured only one face with a diagonal line. Students were to choose the number of the correct answer from the folded cube, (see fig. 10).

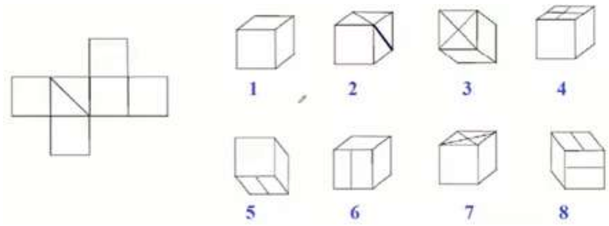

Fig. 10. Simple Cube Test.

The middle level CT presented simple figures on four faces, the goal was for the student to respond with the correct letter of the folded cube, (see fig.11)

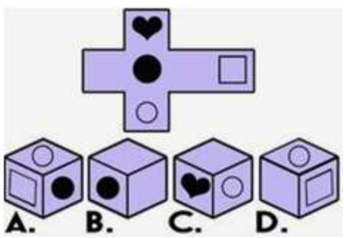

Fig. 11. Middle Cube Test.

For the complex level CT, the unfolded cube had 5 faces with unrelated figures, the student was to choose the letter corresponding to the folded cube, (see fig. 12).

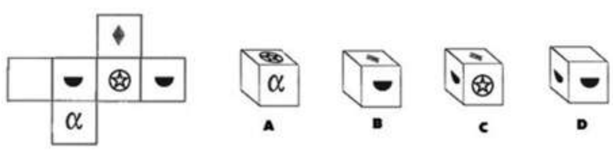

Fig. 12. Complex Cube Test.

At the end of solving the three CTs, the results were analyzed according to the three levels of complexity.

4 Results

At the first moment of the class the students demonstrated a difficulty in understanding what OP are, what their applicability and importance are, but during the demonstration of the third three-dimensional object with relief it was possible to make the students understand how the OP serve to plan to the smallest details the design of the projects.

In the second moment of the lesson, when the teacher applied the Q3DM technology, the students demonstrated a conexion with the tools of the technological resource, they were faster to simulate the rotation of the solids compared to the first moment of the lesson that they had to learn what OP are. The students' behavior showed that the practice was easier compared to the theory.

At the moment of the explanation of the difference of two-dimensional, simple three-dimensional and complex three-dimensional objects it was also noticeable in the behavior of the students that they started to have a detailed analysis of the SV in relation to the surroundings of the classroom, because there were several questions among the classmates if the objects were two-dimensional or three-dimensional and what were the geometric figures of the OP views, these curiosities and analysis impacted in a change of critical visualization of the classroom objects.

At the stage of solving the three CTs, students demonstrated that the exercises were very complex and that they had to reason logically, involving an EV rotation of the cubes to solve the problem, (see fig. 13).

Fig. 13. Student solving the Cube Test.

For the first simple level CT, the data revealed that of the 24 students surveyed, 22 got the result 1 right, corresponding to 92% of correct answers, for medium level CT 21 students chose the correct answer D, corresponding to 87.5% of correct answers. For the complex level CT only

7 students had positive answers, corresponding to 29% of correct answers. These results suggest that the Q3DM technology can be an important tool for teaching technical drawing, as it quickly and interactively transforms complex theory into simple practice by allowing students to see the absent parts of solids. The cube test was employed to measure the SV, revealed that for simple and medium CT the students were able to obtain a correct reasoning of the SV of the unfolded cube. As for the complex CT, the data revealed that there were many difficulties in the SV because it contained more information than the simple and medium CT. In general, the results were satisfactory because the students were able to perceive the applicability and importance of the OP, demonstrate a connection and skills with the Q3DM, and had a medium level development of the 3D SV.

5 CONCLUSIONS

Digital technology can be a resource for classroom teaching, the Q3DM is a tool with potential for the study of OP because it facilitates the visulization of the solid in any position of the observer and the views are clarified. The CT allowed us to measure the level of visual reasoning, of the students to medium level, because the third part of the students in the class could not assemble the complex level unfolded cube. The subject of technical drawing has content that requires a mental rotation of solids in 3D before the passage of 2D resolution, so teachers should look for technological tools that facilitate students a SV of the problem before the process of the passage to the two-dimensional plane. The study aims to motivate for further research to measure students' SV ability using dysgital technologies.

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