Virtual Reality to Solve Spatial Vision Problems: An Experience in High School

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Abstract

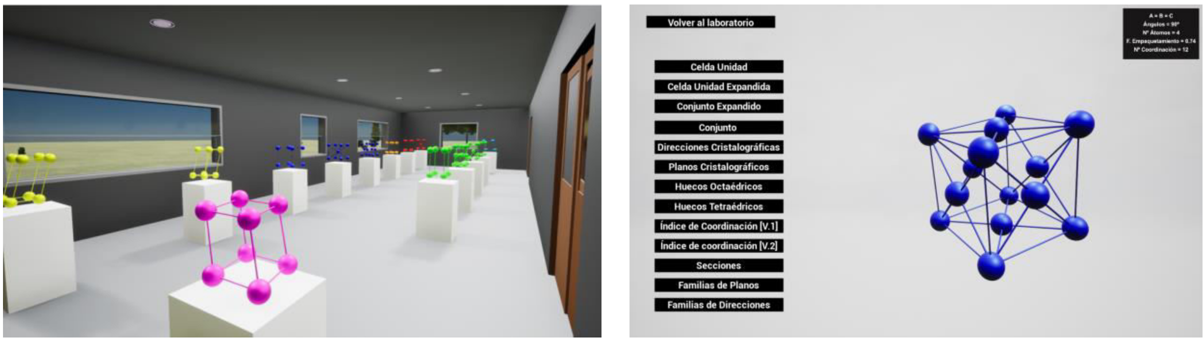
Many students have serious spatial vision problems, and the inability to develop this competence is one of the factors that end up frustrating them in courses where the understanding of three-dimensional concepts is paramount. The Technology course taught in Spanish High Schools is a clear example, since its contents include the explanation of crystallographic lattices, which cause serious spatial comprehension difficulties to many students. Given that it has been proven that virtual reality learning environments can enhance the teaching-learning process, this article evaluates the effectiveness of a Didactic Virtual Tool (DVT) based on virtual reality, which was designed by the authors to increase the visualization capacity of crystallographic lattices. To this end, a real experience with High School students has been carried out. Following this experience, a descriptive research has been conducted through a survey to students, where they are asked about different aspects of the course: (i) user experience; (ii) specific concepts of crystal lattices; (iii) possible improvements in the DVT; and (iv) DVT overall evaluation. The results obtained in this research encourage further progress in the development of such platforms, as students gain improved spatial vision, increased ability to learn and higher motivation.

Keywords: *Virtual reality, didactic virtual tool, materials science and engineering, spatial comprehension, skills, high school.*

1. Introduction

Many students have difficulty with spatial visualization of 3D objects, this ability being related to spatial intelligence. The concept of spatial intelligence emerged in the late 1970s with the theory of multiple intelligences [1] and can be defined as the capacity or ability of people to solve spatial problems, visualize objects from different angles and perspectives or recognize faces and scenes. Linked to this type of intelligence is spatial vision, which is the ability to mentally rotate geometric figures. This skill is of great importance to professions such as architecture and engineering [2,3]. Different studies [4] indicate that spatial visualization is a skill that can be improved through practice and training.

One of the best ways to develop this ability is through virtual tools based on information and communication technologies (ICT), mainly for two reasons: (i) students have a positive attitude towards them [5] and (ii) they offer advantages over other methods [6,7] by providing interaction with 3D objects [8,9]. Furthermore, ICT is essential in our society and affects both the way individuals deal with everyday life and the way organizations and companies operate and manage [10]. Taking this into account, this article evaluates the effectiveness of a new learning paradigm, relying on a Didactic Virtual Tool (DVT), based on virtual reality (VR) technology (Figure 1), which was designed by the authors to increase the spatial comprehension of crystal lattices [11,12]. Crystal lattices is a learning standard that students of Technology courses in Spanish High Schools must acquire before starting any higher education related to technical or engineering degrees. To better understand these concepts, spatial vision plays a fundamental role [11-13].



(a) (b)

Fig. 1. DVT of crystal lattices [11,12]: (a) general view; (b) didactic application

2. Methodology

2.1 Methodological approach

This descriptive research is part of a real experience developed with High School students (16-17 years old). The methodology process in which this research is grounded is structured in three stages (Figure 2): (i) *Master class*: the instructor teaches the most important theorical concepts of crystal lattices; (ii) DVT *first experience*: the instructor shows and explains the DVT to the students and thereafter they are allowed to use it; (iii) *Descriptive research*: the instructor gives surveys to students, where they are asked about different aspects of the course.

Fig. 2. Methodology process outline

2.2 Survey structure

In order to know and quantify students' opinions about the DVT effectiveness for the learning of crystal lattices, as well as their degree of conformity with it, a survey is designed. In this survey, 10 students answer different questions structured in the following blocks: (i) User experience: questions related to influential aspects in the user-DVT interaction; (ii) Specific concepts of crystal lattices: questions aimed at checking the degree of knowledge about specific concepts of the different crystal structures; (iii) Possible improvements in the DVT: questions to obtain information about potential enhancements to be developed in future platform updates; and (iv) DVT overall evaluation: questions related to the DVT effectiveness as a didactic tool.

3. Results

This section shows the survey results. In the first block of questions, user experience, students evaluate technical aspects of the user-DVT interaction (Figure 3): (i) Question 1 (Q1): difficulty in visualizing 3D objects; (ii) Question 2 (Q2): degree of understanding of the operating instructions of the virtual platform; (iii) Question 3 (Q3): DVT user-friendliness; (iv) Question 4 (Q4): ease of understanding of different crystal lattices; (v) Question 5 (Q5): quantification of problems found when using the DVT; (vi) Question 6 (Q6): degree of students' motivation; and (vii) Question 7 (Q7): degree of usefulness of the DVT graphical interface.

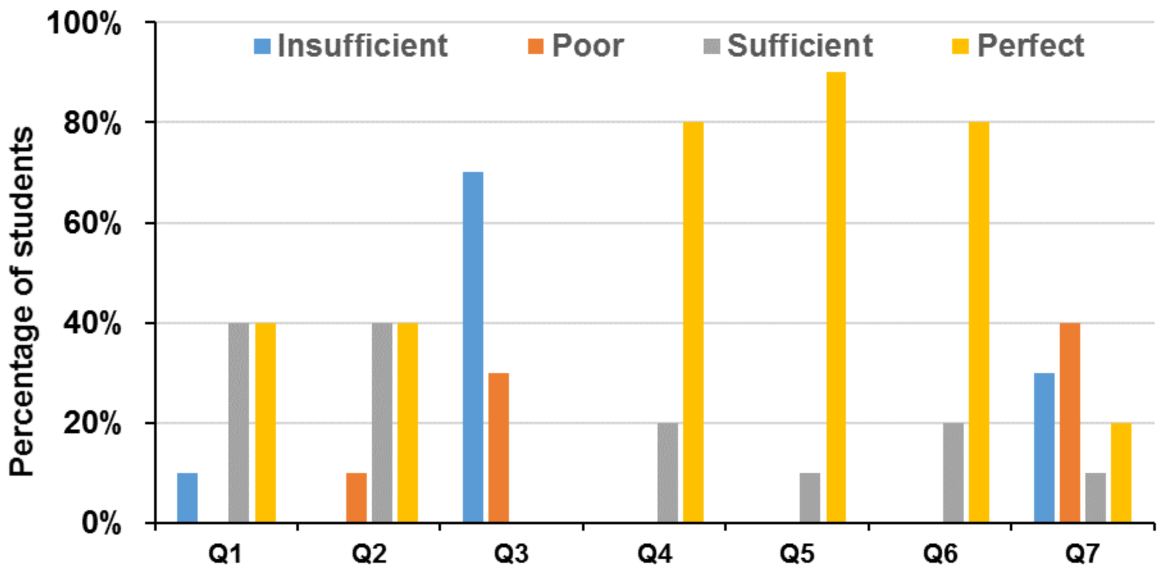


Fig. 3. Survey results: user experience.

In the second block of the survey students are asked about specific concepts related to the different crystal structures (Figure 4): (i) Question 8 (Q8): spatial vision; (ii) Question 9 (Q9): crystallographic planes, crystallographic directions and coordination index; (iii) Question 10 (Q10): properties of crystal lattices; (iv) Question 11 (Q11): degree of understanding of crystal lattices; (v) Question 12 (Q12): difficulty in understanding different crystal structures before using the DVT.

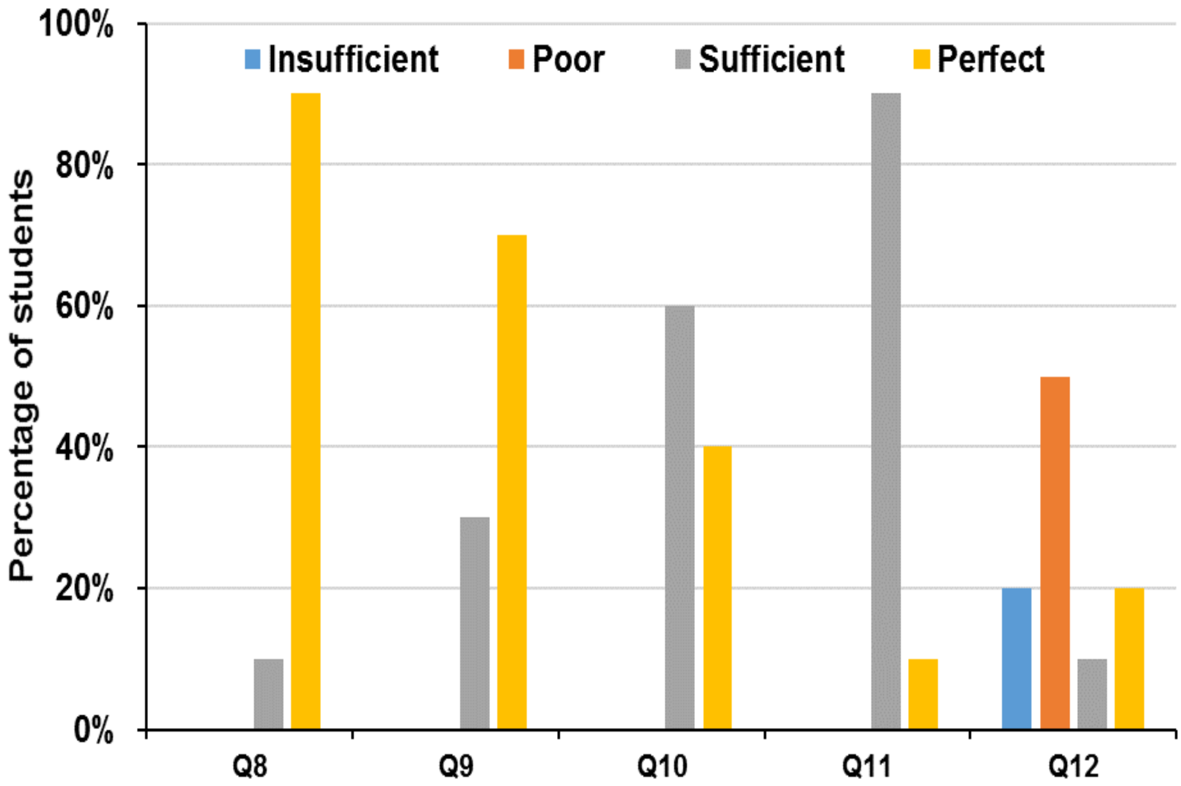


Fig. 4. Survey results: specific concepts of crystal lattices.

In the third block of the survey, linked with possible improvements in the DVT, students answer yes or no to these questions (Figure 5): (i) Question 13 (Q13): is this DVT applicable to other subjects?; (ii) Question 14 (Q14): would you make any improvement in the DVT?; and (iii) Question 15 (Q15): can DVTs have other applications? Finally, with regard to DVT overall evaluation, only one question is asked: (i) Question 16 (Q16): is the DVT effective as a teaching tool? (Figure 6).

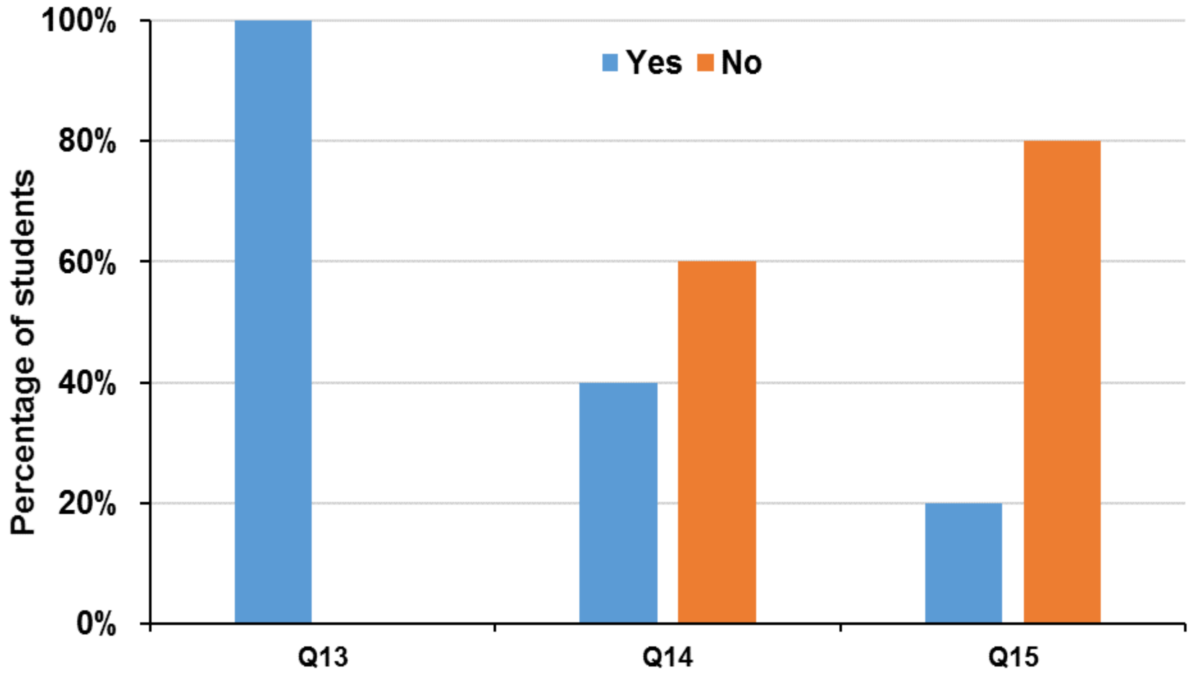


Fig. 5. Survey results: improvements in the DVT

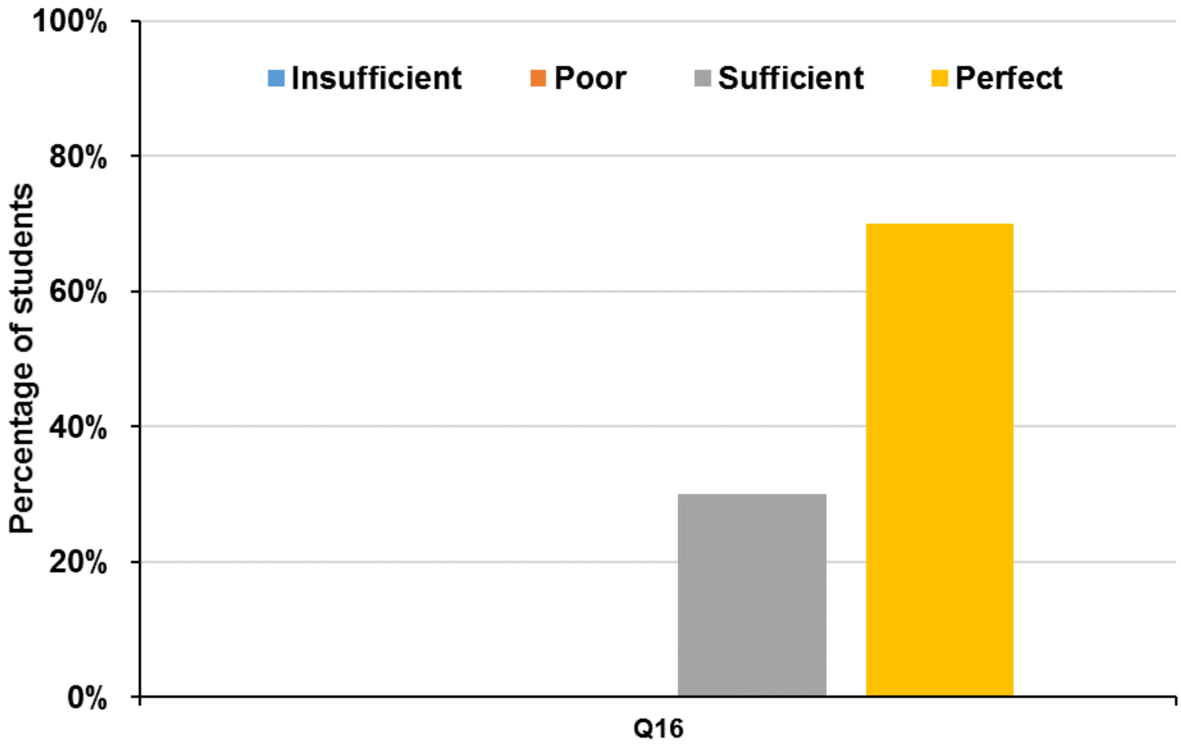


Fig. 6. Survey results: DVT overall evaluation.

4. Conclusions

The results obtained in this study reveal that this virtual reality learning environment designed to reinforce the spatial comprehension of crystal lattices is considered a useful tool by High School students. Thanks to this DVT, students with less developed spatial intelligence can better understand concepts related to crystal systems. Finally, the results obtained encourage further progress in the development of new DVTs with educational purposes.

References

[1] Gardner, H. “Frames of mind: the theory of multiples intelligences”, New York: NY: Basic Books, 1983.

[2] Hsi, S.; Linn, M.C.; Bell, J. E. “The role of spatial reasoning in engineering and the design of spatial instruction”, *Journal of Engineering Education, 86*(2), 151-158, 1997.

[3] Vergara, D.; Rubio, M.P.; Lorenzo, M. “On the use of pdf-3D to overcome spatial visualization difficulties linked with ternary phase diagrams”, *Education Sciences*, *9*, 67, 2019.

[4] Crown, S.W. “Improving visualization skills of engineering graphics students using simple JavaScript web based games”, *Journal of Engineering Education, 90*(3), 347-355, 2001.

[5] Vergara, D.; Rubio, M.P. “PDF-3D as educational technology”, *Eduweb*, *Revista de Tecnología de Información y Comunicación en Educación, 12*(2), 205-213, 2018.

[6] Oz, C.; Serttas, S.; Ayar, K.; Findik, F. “Effect of virtual welding simulator on TIG welding training”, *Journal of Materials Education, 37*(5-6), 197-217, 2015.

[7] Vergara, D.; Extremera, J.; Rubio, M.P.; Dávila, L.P. “Meaningful learning through virtual reality learning environments: A case study in materials engineering”, *Applied Sciences, 9*(21), 4625, 2019.

[8] Vergara, D.; Extremera, J.; Rubio, M.P.; Dávila, L.P. “The technological obsolescence of virtual reality learning environments”, *Applied Sciences, 10*(3), 915, 2020.

[9] Vergara, D. “Introduction of virtual laboratories in the education of the XXI century”, *Eduweb*, *Revista de Tecnología de Información y Comunicación en Educación, 13*(2), 119-128, 2019.

[10] Zhang, P.; Aikman, S. “Attitudes in ICT acceptance and use”, *Human-Computer Interaction Interaction Design and Usability*, 1021-1030, 2007.

[11] Vergara, D.; Sánchez, M.; Garcinuño, A.; Rubio, M.P.; Extremera, J.; Gómez, A.I. “Spatial comprehension of crystal lattices through virtual reality applications”, Proceedings of the 12th annual International Conference of Education, Research and Innovation, Seville, Spain, 2019, 1291-1295.

[12] Extremera, J; Vergara, D.; Davila, L.; Rubio, M.P. “Virtual and augmented reality environments to learn the fundamentals of crystallography”, *Crystals*, 2020, *accepted article*.

[13] Vergara, D.; Rubio, M.P.; Lorenzo, M. “A virtual resource for enhancing the spatial comprehension of crystal lattices”, *Education Sciences, 8*(4), 153, 2018.