Using NeoTrie VR for STEM Education in Virtual Reality

Diego Cangas[1], Antonio Codina[2], Dante Y. Chavil[3], José M. Fernández[4], Mª Mar García[5], Jacob Kamerling[6], Encarnación López[7], Grazyna Morga[8], José L. Rodríguez[9], Isabel Mª Romero[10]

Virtual Dor, Spain [1]
University of Almería, Spain [2, 5, 9, 10]
National Technological University of Lima Sur, Peru [3]
IES Pablo Picasso, Málaga, Spain [4]
CSG Willem de Zwijger, Schoonhoven, Netherlands [6]
IES Reyes Católicos, Vélez-Málaga, Spain [7]
Zespół Szkolno-Przedszkolny, Żernica, Poland [8]

Abstract
NeoTrie VR is a software package to play and generate activities in virtual reality for educational purposes. Our teaching experience during the last few years indicate a high motivation in the students from primary to university levels, while allowing them to play, learn and create figures based on 3D geometrical structures. This project is mainly supported by the University of Almería, in the framework of a European Scientix project.

Keywords: *Virtual Reality, Innovative Education, 3D Geometry*

1. Introduction
Nowadays, emerging technologies like virtual reality can provide educational immersive and interactive experiences which are very attractive and motivating for students. The experience of using the dynamic geometry software NeoTrie VR (shortly Neotrie, see Figure 1) in real classrooms by the authors confirm that this technology stimulates the acquisition of 3D visual and spatial thinking, among other skills. Roughly speaking, this tool enables pupils to create, manipulate, and interact with 3D geometrical objects and 3D models in a totally immersive scenario. It also permits teachers to easily design activities and games to solve plane and spatial geometric problems, without special programming knowledge and straight from the virtual reality environment.
We present a brief description of the target students, the topics covered, the methodology used, and the results obtained by some members of the project. Some STEAM applications are also given, finishing with some conclusions. A more deep and detailed research article is being produced by Codina, Rodríguez, Romero in [3].

Figure 1: Some dynamic geometry tools in Neotrie. See more information at [7].

2. Participants, topics, and methodologies

In Poland school, lessons were given by Morga to students from 10 to14 years old, in different class groups with 16-26 pupils. For each age group and based on the math Poland core curriculum, Neotrie lessons were referring to angles, polygons, prisms, pyramids, and fractions (see Figure 2). In most of the classes, the software was used during the whole lesson, or only in a part of it, depending on the needs. At the beginning of each lesson and in 3 or 5 pupil's groups, the tasks were assigned to be carried out using Neotrie. To solve the tasks, students had to develop their own strategies and use adequate Neotrie's tools. Also, one delegate performed the task in Neotrie. Some lessons or tasks were only taught by the teacher with Neotrie, and in some cases the teacher did not use the board but wrote down all the important information using the software [1].

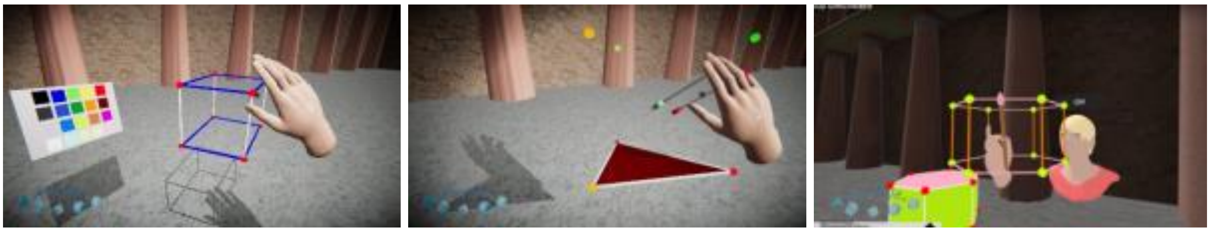

Figure 2: Making a cube; making a prism with the parallel tool; painting parts of a prism (Morga).

In Netherlands, Kamerling worked with various groups of students from 12 to 18 years old. In a didactical experience with 12 years old students, they got insight in 3D rotations and reflections, as well as in the search for optimal transformations to fit two half-cubes into a cube by using Neotrie and their previous knowledge about 2D rotations and reflections. In other didactical experience, with students of 15, 16, 17 aged, Neotrie provided an active way for students to study the Platonic solids and their duals. Some of them also studied Archimedean solids and fractal structures made with Platonic solids (see Figure 3). During the lessons, usually two groups of three students worked with Neotrie (one or two lessons per group). In each group one of the members became a "Neotrie coach" for a new group [4].

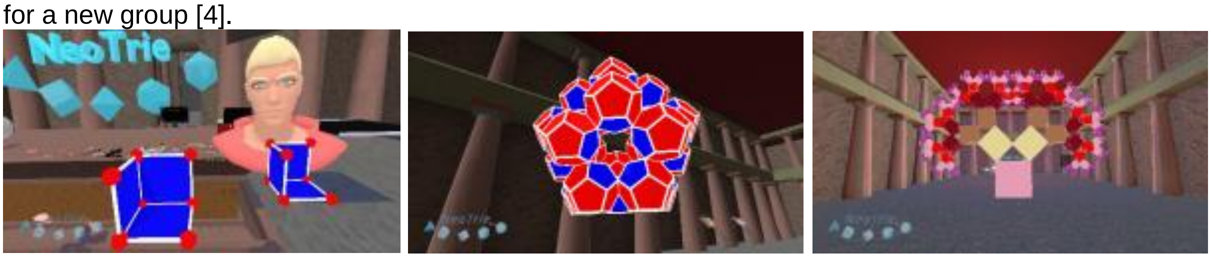

Figure 3: Searching optimal rotations; iteration of a dodecahedral fractal; fractal tree (Kamerling).

In Spain, Fernández (in collaboration with López) worked in his high school with 23 students aged 12 and 13. The didactical experience referred to plane geometry content but using Neotrie, including the area and perimeter of polygons. The experience was carried out in pairs, while one built and obtained the measurements, the other worked in paper and pencil during the activities, then they interchanged the roles. Fernández and López trained 12 students in the use of Neotrie to ensure that there was always someone in the group who knew how to handle it and guide their classmates (see Figure 4).

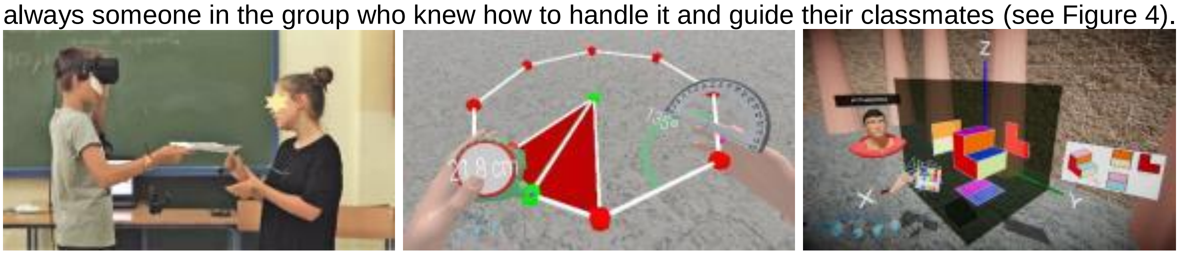

Figure 4: A pair of pupils working collaboratively; measuring distances and angles; multi-view plane projections (Fernández and López).

On the other hand, García and Romero coached about 110 students for teachers for Primary School at the University of Almería, and 50 children aged 11 and 12, from two primary school classes (Figure 5). The topic was the introduction to basic 3D figures (pyramids, prisms, and other polyhedra). They followed Vinner´s approach [6] of concept definition and concept image, including prototypical and non-prototypical examples, as well as counterexamples made out with Neotrie. Due to Covid-19 restrictions, different dynamics were orchestrated online, in the case of preservice teachers, using manipulatives and a [gallery of prisms](#) on the website of Neotrie [7]. Videos in Edpuzzle were made up, together with questions. For school children, various activities were orchestrated by the teacher, with the same materials, during 5 classroom sessions. Children worked in small groups most of the time, and they had some whole-group discussions.

Figure 5: Galery of examples and counterxamples of prisms in Neotrie; pupils using VR glasses for mobile phones; and students clasifying prisms and non-prisms (García and Romero).

Also in Spain, Rodríguez tested during the academic courses 2017-2019, the first versions of Neotrie with his master students for Secondary School Math teachers at the University of Almería. Among other topics, they learn how to use Neotrie to study the main properties of the platonic solids, semiregular tessellations, and some basic fractals (Figure 6).

Figure 6: Master's students making tessellations with manipulative materials; and virtually in Neotrie; Sierpinski triangle in Neotrie (Rodríguez).

After this period, Chavil, Romero and Rodríguez sought in [2] a first approach to the teaching of fractals using Neotrie, with 12 students aged 12-13, in groups of 4 people. Fractal geometry is not addressed in the Spanish curriculum. Hence, the fractal concept was explained to them in a first session, with the main emphasis on the property of self-similarity and the recursive character. A second session was devoted to learning how to use Neotrie, making basic constructions of Euclidean geometry. In the last session, they were asked to build known fractals in both 2D and 3D with the tools of Neotrie (Figure 7).

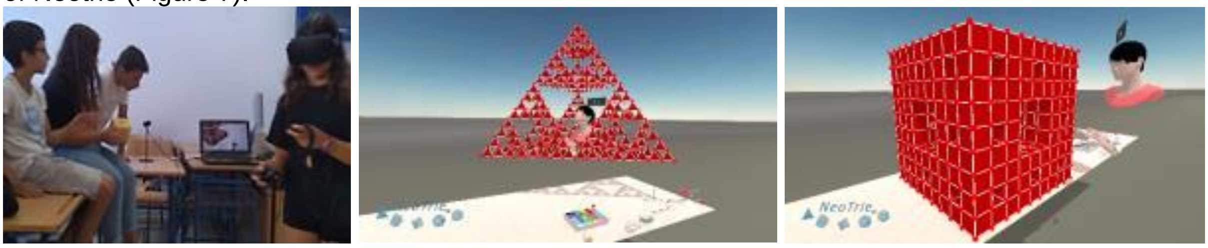

Figure 7: Making fractals; Sierpinski tetrahedron; and Menger sponge [2].

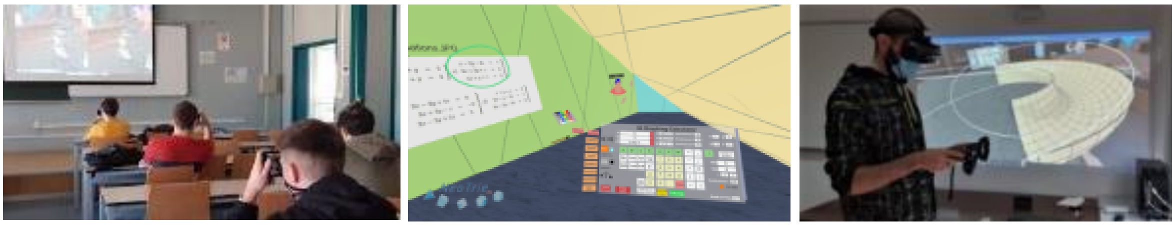

Figure 8: Students using the VR glasses for mobile phones; intersecting planes with the 3D graphing calculator; and student representing a parametric surface [5].

We finally highlight the use of the 3D graphing calculator by Rodriguez to teach Elementary Geometry to math degree students aged 18-19, and to study parametrized curves and surfaces by math degree students aged 22-23. During the last year, Rodríguez also used VR for distance teaching and pre-recorded mono and stereoscopic videos in his lessons (see Figure 8 and [5] for more information).

3. Results

After each lesson, Morga kept a log with the information about the date, topic of the lesson, number and age of the pupils and a description of the activities to be performed with the use of Neotrie, necessary tools, the advantages, and disadvantages as well as recommendations. These recommendations provide guidelines and suggestions to teachers on how to organize a lesson using Neotrie in the most effective way. Recommendations and conclusions based on the observations can be founded in [1]. Educational videos were recently recorded in Neotrie on basic information about prisms and pyramids to be used for distance teaching (see the video https://youtu.be/-vE4cCd-pqM).
In the Kamerling experience, he observed that this active form by using Neotrie consisted not only in acting, but especially in the development and implementation of mathematical thinking in action. He noted that Neotrie allowed students to extend their prior knowledge of 2D to 3D rotations and reflections. Furthermore, the “Neotrie trainer” system allowed Kamerling to work with groups that did not use Neotrie, because the students' aptitude and motivation as Neotrie trainers were so good that it was only needed in special situations [4].
It is recurrent that use of Neotrie has improved the motivation in all age students, but Fernández observed that his students enhanced their ability to concentrate on the tasks, especially in students with difficulties, since by choosing any of them for the previous training, their consideration within the group, their self-esteem and their effort had improved academic for maintaining the trust placed in him. For 12-year-old students, they detected that the activities allowed the pupils emulated everyday actions such as measuring objects or understanding their properties, thus internalizing the procedure that they must then apply numerically. Finally, working in a cooperative environment, collaboration among equals and attention to diversity have contributed to enhancing the benefits of using this software in class. On the other hand, it is known that students between 12 and 15 years old tend to have difficulties identifying the dihedral projections and, they to lifting the 3D figure from its projections. In this case, the use of the dynamic multi-view plane projections allowed students to easily establish relationships between what is built in space and its representations on projection planes, being able to correct and modify them in real time (see the video https://youtu.be/KyxvQqR5pxM).
For both student teachers and schoolchildren coached by García and Romero, Neotrie has contributed to developed favourable attitudes towards mathematics and to enhance their understanding of the concepts of pyramid and prism, from the identification of its relevant and irrelevant properties. Students at both levels admitted enjoying more and becoming more involved in math activity while improving their math vocabulary and geometric proficiency. The application of Vinner's model promoted for all students a more meaningful and less rote learning of the characteristics and elements of prisms and other polyhedra, and NeoTrie has been a great support for constructing non-prototipical examples and counterexamples [2].
The use of Neotrie favoured the introduction of fractals and their learning in secondary's students. They were able to identify the existence of self-similarity and the recursive character presented in fractals. Furthermore, throughout the process, the students were intrinsically motivated, showing enjoyment and satisfaction with what they were doing. As in previous experiences, the students showed a high degree of concentration as well as the desire to solve new challenges.
Finally, all the experiences above also helped the Neotrie developers to know the technical errors that the software presented to correct them and increase their potential.

4. Further applications

As we have seen, Neotrie pays special attention to those aspects of Geometry of the curriculum from primary to university levels, but it could be also applied in STEAM orientation where Geometry plays a relevant role, but normally causes visual and spatial reasoning difficulties with other tools and methodologies (see Figures 9, 10).
Neotrie can be used as an editor of VR scenes for various activities as it is illustrated in, and 10, with the possibility of inserting objects of different nature, like texts, photos, videos, sounds, 360 panorama pictures, OBJ and STL objects to export to 3D printer (see Figure 11).

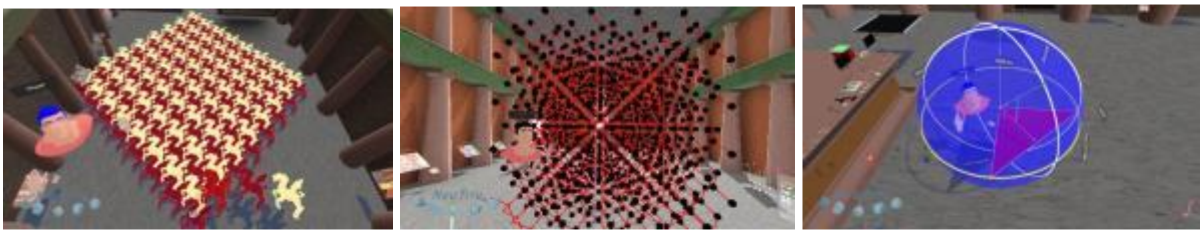

Figure 9: Art production of an Escher tiling; constructing the diamond structure; stars coordinates of from the inside of a celestial sphere.

Figure 10: Measuring the height of a mountain; scanning 3D objects; and their sections.

Figure 11: Music balls to play; managing 360º pictures, editing OBJ or STL objects for 3D printing.

5. Conclusions

We have briefly shown part of the whole work carried out in the Neotrie VR project during the last years. We would like to conclude highlighting some items achieved by the students thanks to the use of Neotrie:

- It has helped them to organized geometric knowledge and increased their creativeness.
- It has improved their spatial reasoning and understanding the properties of certain 3D structures.
- It has enhanced them understanding of geometric concepts of the math curriculum.
- It has enabled them to become motivated and more involved in math activity, improved their math vocabulary and geometric proficiency.

Virtual reality makes it easy to treat 3D geometry in distance learning, with mono and stereoscopic videos pre-recorded directly in Neotrie. The project is still open and addressed to teachers and pupils from primary school to university levels, interested in educational applications with virtual reality.

References

[1] Cangas D., Morga G., Rodríguez J.L. “Geometric teaching experience with Neotrie VR”, Psychology, Society, & Education, Vol. 11(3), 2019, pp. 355-366.

[2] Chavil D.Y., Romero I.M., Rodríguez J.L. “Introduction to the concept of fractal in secondary education using immersive virtual reality”, From the South, Vol. 12 No. 2, Lima; 2020, 615-629.

[3] Codina, A., Rodríguez, J.L., Romero, I.M. “Introducing virtual reality in the classroom: teaching and learning geometry with NeoTrie VR”, in preparation, 2021.

[4] Kamerling J. “VR-brillen in de wiskundeles”, (2020) https://www.voortgezetleren.nl/post/vr-brillen-in-de-wiskundeles-een-boost-voor-het-ruimtelijk-inzicht-van-leerlingen/

[5] Rodríguez, J.L. “Exploring dynamic geometry through immersive virtual reality and distance learning”. In Mathematics Education in the Age of Artificial Intelligence, Berlin: Springer, 2021.

[6] Vinner, S. “Concept definition, concept image and the notion of function”. International Journal of Mathematical Education in Science and Technology, 14(3), 1983, 293-305.

[7] Web of the NeoTrie VR project: http://www2.ual.es/neotrie