Heliyon 8 (2022) e10316

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Degree of motivation and acquisition of visuospatial perception after the incorporation a video game in the learning of mathematical knowledge

Jorge Guerra-Antequera [*], Juan-Antonio Antequera-Barroso, Francisco-Ignacio Revuelta-Domínguez

Teacher Training College, University of Extremadura, Spain

ARTICLE INFO

Keywords:
Video games
Mathematics
Spatial perception
Motivation

ABSTRACT

The aim objective of this study was to analyze the incorporation procedure for the Portal 2 video game in the subject Mathematical Knowledge in Early Childhood Education. Two specific objectives were proposed: (a) to consider whether the inclusion of a video game is a motivating educational resource, and (b) to determine the degree of knowledge related to visuospatial perception acquired through interaction with the video game.

A total of 170 students from the Faculty of Education Sciences of the University of Cádiz participated in this study.

Three variables were analyzed: the use of the video game as a resource, the degree of motivation towards mathematics-related learning, and the acquisition of visuospatial skills.

The results show that the students affirmed the video game's suitability as a learning resource, although as a supplementary resource to the dynamics of the subject, highlighting the strong motivational factor and the set of knowledge acquired.

1. Introduction

Spatial perception can be framed within one of the five areas that comprise didactic-mathematical knowledge developed in Early Childhood Education, specifically within the spatial-geometric area.

Mathematics and mathematics-related subjects tend to be among the most unpopular subjects in initial (Preschool and Primary school) and secondary (Middle and High school) levels of education, and even at tertiary level, which produces a certain sense of fear among students. Some associate this fear of the subject with the absence of a solid educational structure in the early stages of education. Due to the complexity of some terms and concepts, students end up carrying this fear of mathematics with them throughout their academic life, which creates feelings of insecurity, fear, and in some cases frustration with the subject (Gresham and Burleigh, 2019; Olson and Stoehr, 2019; Peker, 2009; Swars et al., 2006). Therefore, it is worth questioning the methodology and the didactic means used to impart this knowledge, and to inform people of how useful it can be in their daily lives. Reviewing the results obtained by Spain in the PISA ("PISA is the OECD's Programme for International Student Assessment.") tests (Echazarra and Schwabe, 2019; Ministry of Education and Vocational Training, 2019), they also reveal that the mathematical competence results are stagnant; in comparison with the results achieved in the previous years of the test, there is no favorable evolution (see Table 1).

The tests present situations that occur in everyday contexts. Using situations from daily life should stimulate students to investigate and look for answers to these situations. For example, a supermarket purchase involves employing different skills that lead to the successful completion of a transaction that starts with counting, which ranges from adding up the number of products to be purchased to the amount to be paid for the products. Other activities that should be present in this type of transaction are spatial perception-related, such as moving in order to find a certain product, estimating the weight of the goods to be purchased in order to subsequently make a recipe, and finally, the process of payment.

A situation as ordinary as the one shown in the previous paragraph demonstrates the need to make use of the mathematical knowledge that, despite being very necessary for students' life and work performance, causes them so much fear or anxiety. Perhaps all these feelings that demotivate students and cause this indifference toward mathematical knowledge can be traced back to the excessive explanation of theorems, demonstrations, and repetitive exercises that are not taken from a real-world context.

* Corresponding author.
E-mail address: guerra@unex.es (J. Guerra-Antequera).

https://doi.org/10.1016/j.heliyon.2022.e10316
Received 24 December 2021; Received in revised form 12 May 2022; Accepted 9 August 2022

Table 1. Evolution of estimated mean scores in mathematics.

	2009		2012		2015		2018	
	Score	ET	Score	ET	Score	ET	Score	ET
Spain	483	2,1	484	1,9	486	2,2	481	1,5

Note: Adapted from the PISA Report 2018 (Ministry of Education and Vocational Training, 2019).

For this reason, teachers intend to motivate attention and relevance for the acquisition of this knowledge through more interesting activities, exercises, and problems that are motivating and closer to their reality or everyday life (Csikszentmihalyi, 2020). In other words, to create or present situations that produce a greater interest in the activities, in such a way that students can identify and mobilize mathematical knowledge, thus making motivation one of the main tools for the acquisition of mathematical knowledge (Alsina, 2011; Alsina and Domingo, 2007). These activities allow students to reflect on the task to be carried out, and to share it with their classmates, enriching the result of the task as indicated by Carmona, Antequera-Barroso & Cardeñoso (2019). These authors asked their students to design and build their ideal Early Childhood Education school; the school in which they would like to work in the future. This task involved the identification and mobilization of didactic-mathematical knowledge related to the spatial-geometric domain. With this task, the students were able to reflect and discuss among themselves how to apply their knowledge of the field in the design and construction of their ideal school. They expressed their ideas on paper through sketches, and through manipulative material such as polydron, polycubes, Geomag or Meccano, among others. The use of these elements facilitates the understanding of abstract concepts associated with the knowledge (López et al., 2011) that students are trying to identify and mobilize.

A question that arises during the activity-planning phase is how can these students be motivated by these activities to carry them out, using attractive and motivating resources. Reviewing the results obtained by Spanish students, according to the PISA report, the scores have fluctuated over the years. Currently, the scores are similar to those obtained in 2006; far from the average scores recorded by the OECD. Therefore, we can highlight that Mathematics is still one of the subjects in which students do not receive sufficient motivation to get involved in the activities, and therefore do not realize how important these activities are in helping them understand the world around them (Figure 1).

The focus of interest of this study was 2nd year undergraduate students taking the subject Mathematical Knowledge in Early Childhood Education, part of the B. Ed. in Early Childhood Education in the Faculty of Education Sciences of the University of Cádiz. For this purpose, an overall aim was proposed in order to analyze whether the Portal 2 video game is suitable for incorporation in the subject Mathematical Knowledge in Early Childhood Education, through the assessment of teachers undergoing initial teacher training. Two specific objectives were also proposed, namely: (a) to assess the inclusion of a video game as a motivating educational resource, and (b) to determine the degree of knowledge related to visuospatial perception acquired through interaction with the Portal 2 video game.

The incorporation of video games in the educational context, although not a recent addition, sometimes acquires a certain complexity due to existing prejudices in the face of a purely recreational element (Guerra, 2017). However, the great relevance of these resources and their permeability in social and cultural contexts allows teachers to obtain them in order to provide them with pedagogical meaning and to incorporate them as classroom resources (Barr, 2017, 2018; Bavelier et al., 2012; Devlin, 2011; Gee, 2004; Granic et al., 2014; Marín, Morales and Reche, 2019; Martín et al., 2017; Steinkuehler and Squire, 2014).

Several studies have already been carried out on the incorporation of video games as a resource in the subject of Mathematics (Egenfeldt-Nielsen, 2006; Mitchell and Savill-Smith, 2004). However, it is not a subject in which studies or initiatives that incorporate these tools stand out; as these tools, resources, or methodologies are not as well related to the subject as serious games (Dele-Ajayi et al., 2016), board games (Laski and Siegler, 2014; Vogt et al., 2018) or gamification (Faghihihi, Brautigam, Jorgenson, Martin, Brown, Elizabeth and Maldonado, 2014; Jagušt et al., 2018).

More recent studies propose the use of video games linked to the acquisition of skills specific to the curriculum proposed by various agencies, called 21st century skills (El Mawas, Bradford, Andrews, Pathak and Muntean, 2018). In this sense, the skills acquired in the educational context need to be useful for the individual's personal and professional performance. Therefore, it is necessary that the skills learned at school are efficiently transferred outside of school, into a practical setting (Albarracín et al., 2019; Kristjánsson, 2013; Shao et al., 2019).

Most of these studies and experiences use educational games or serious games that have a lower impact than commercial video games and are practically unknown; whose mechanics, although similar, are not the same as those used in the games the students usually interact with.

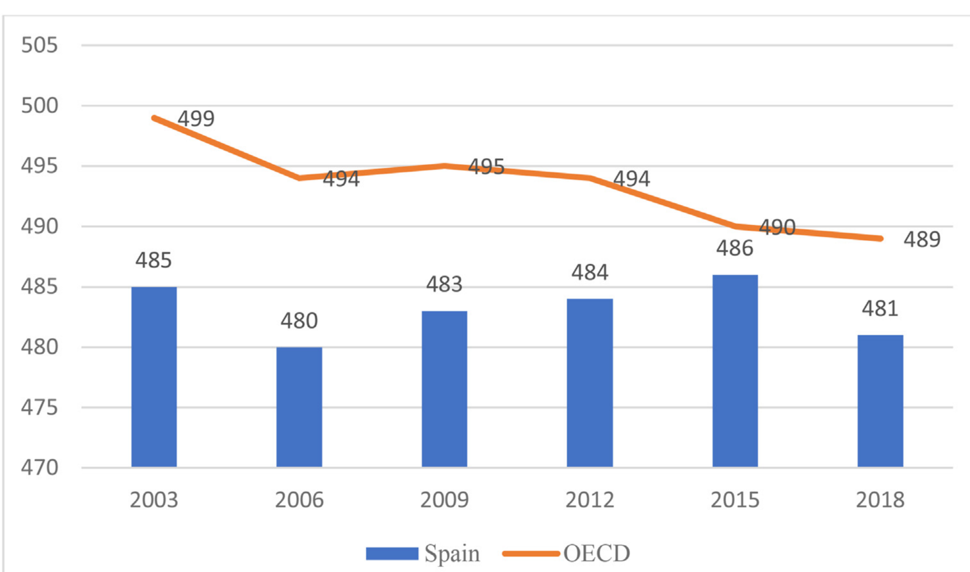

Figure 1. Evolution of the estimated mean scores in mathematics. Source: Adapted from the PISA report 2018 (Ministry of Education and Vocational Training, 2019).

Therefore, in this study, we have selected a commercial video game that stands out for several reasons, such as its simple means of teaching basic controls, its low-end PC requirements, its aseptic scenarios with relevant, non-overloaded stimuli, and its futuristic plot. The game takes place in a laboratory controlled by an artificial intelligence (AI) called *GLaDOS* (*Genetic Lifeform and Disk Operating System*) that subjects the protagonist, *Chell*, to different mathematical logic tests in order to leave the laboratory, which can be a motivating element (Coller and Scott, 2009; Ventura et al., 2013). This last aspect is important, as some studies have noted (Devlin, 2011; Tarampi et al., 2016; Shute et al., 2015) that spatial perception is enhanced when a human figure is taken as a reference in front of an object. Therefore, this fact could be used as an element of motivation, since the protagonist needs help solving the different challenges that arise in each level, and also in determining if the video game is useful as an educational tool for its intended purpose. In order to solve the various tests, the students need to structure the space, as it is a video game played in first person; to discover the position of the various objects that make up the room, which they may or may not use; and to figure out how to get to the door that will lead to the next room with the help of different elements within the room. They will establish the relationships that exist between objects, walls, and doors, and carry out all of this with the help of a *portal* gun that allows them to move through the laboratory created by the AI in each of the levels (Figure 2). In this fashion, the students will be able to identify and mobilize the necessary mathematical knowledge specific to the field to solve the challenge in a fun and unusual way (Adams et al., 2016; Pittman, 2013; Shute et al., 2015).

Through Portal 2, one can create tests that identify and mobilize knowledge related to the spatial-geometric domain. In this study, the students were specifically working on the structuring of space, which was occupied by the objects or human figures, and visuospatial skills (Spence and Feng 2010; Green and Bavelier, 2007, 2012; Ventura et al., 2013). Shute, Ventura and Ke (2015) classified perception into three stages: (a) the first stage is the perception of self, which in the case of Portal 2 is simple, as it is a first-person video game (that is, the player sees through the eyes of the protagonist), which helps to determine the character's position in space; (b) in the second stage, the objects in the space are determined and their position in the different parts of the space is imagined; this is very useful for understanding the space and the objects from different perspectives; (c) the third stage refers to the construction of a cognitive map of the space by the players; that is, a mental representation of the place where the action will take place.

The player goes through all these stages to understand spatial development; they are learning phases that begin with understanding the place that the character occupies in a given space, the relationship between the space and the objects within, the creation of internalized routes to move through said space and, in the case of Portal 2, to solve the required puzzles in each level.

As mentioned above, these strategies can be very useful for the individual when transferring the skill obtained from the video game to their daily life; for example, when identifying an object/person or when arriving to a new city and looking for a building with a certain description. To do this, it is necessary to identify objects, shapes, or places that serve as reference points so that the target can be located. Therefore, relationships are established between the elements that compose a space; if it is closed, if it is next to another thing or place, if there is any representative object; that is, (a) topological relationships. In the same way, (b) projective relationships are established by placing objects or places in front, behind, to the right, or to the left. In the case of (c) metric or Euclidean relationships, the position or location of an object or person is determined using your own body as a reference system initially and then transferring that reference system to other objects or people.

In this sense, the development of the body reference system is carried out during the period in which students start school; that is, during Early Childhood Education, where they will use their own body to relate to their environment and to the objects that compose it, as well as their knowledge.

2. Methodology

The aim of this study was to discover what contributions the inclusion of the Portal 2 video game in the classroom could offer; the scarcity of a bibliography places it within the exploratory studies. The methodology used to approach the research was quantitative, as the acquisition of data was based on numerical measurement and statistical results.

The sample (n = 170) was composed of 161 women and 9 men; 95% and 5% of the sample, respectively. The participants were between the ages of 18 and 50 (see Table 2) and were 2nd year students in the B. Ed. Early Childhood Education of the Faculty of Education Sciences of the University of Cádiz. An informed consent form for participation was proposed to the participants. This research did not go through an ethical committee because the university does not have one.

To develop the experiment, the students played the Portal 2 video game on PCs and the practical session was divided into different phases;

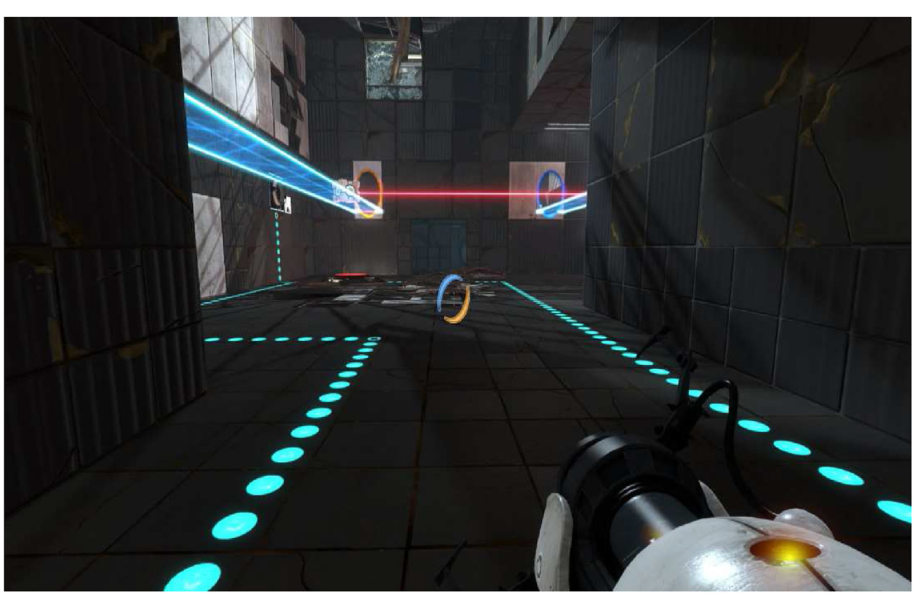

Figure 2. Screenshot of a Level from the Portal 2 Video Game. Source: Own elaboration.

Table 2. Frequency table of the age of the students analyzed.

Ages (years old)	Frequency	Percentage
18	2	1%
19	56	33%
20	17	10%
21	26	15%
22	26	15%
23	22	13%
24	13	8%
25	4	2%
26	1	1%
27	2	1%
50	1	1%

Source: Own elaboration.

(a) the first phase was dedicated to the explanation of the experiment, which included explanations of basic mathematical concepts about spatial perception, geometry, and the physical concept of the portals on which the mechanics of the game are based; (b) in the second phase, the controls, concepts, and narrative context of the game were explained to help motivate the students regarding the tests and/or activities to be developed; (c) the third phase was used to explain how to access the questionnaire and how to fill it in; and (d) the fourth phase included the installation of the game by the students on their laptops. Once installed, the students were given a series of instructions to start the game. A standard configuration for the keyboard was provided so that they knew the basic movements of the main character, which they could modify to their liking if they chose to; (e) in the fifth phase, the students were told that they could explore the video game freely for 45 min. In order to collect the data, they were asked to take notes on didactic aspects that they considered viable for application in the classroom, according to their knowledge as teachers undergoing initial teacher training; this highlighted spatial-geometric knowledge (see Figure 3).

Three instruments were used to carry out this study: (a) the Portal 2 video game, (b) a questionnaire created for the study, and (c) the statistical analysis software SPSS.

In order to collect all this information, the students were given access to a semi-closed questionnaire in Google Drive through the Mathematical Knowledge in Early Childhood Education's virtual campus. This questionnaire (see Figure 4) was divided into seven sections, although for this study, we will focus exclusively on the first two. The first section was used to collect the students' personal data, which preserved their anonymity. The second section was, in turn, divided into two parts. The first part gathered information related to the identification and mobilization of didactic-mathematical knowledge, and its application in the different stages of the Spanish educational system. In the second part, the students had to include the strengths, weaknesses, opportunities, and threats posed by the Portal 2 video game in relation to its use in the classroom.

The SPSS 24 statistical software was used to analyze the data collected in the form.

3. Results

The first question the students had to answer was related to whether they considered themselves to be video game players. Although the results show that 114 women (71%) and 4 men (44%) did not consider

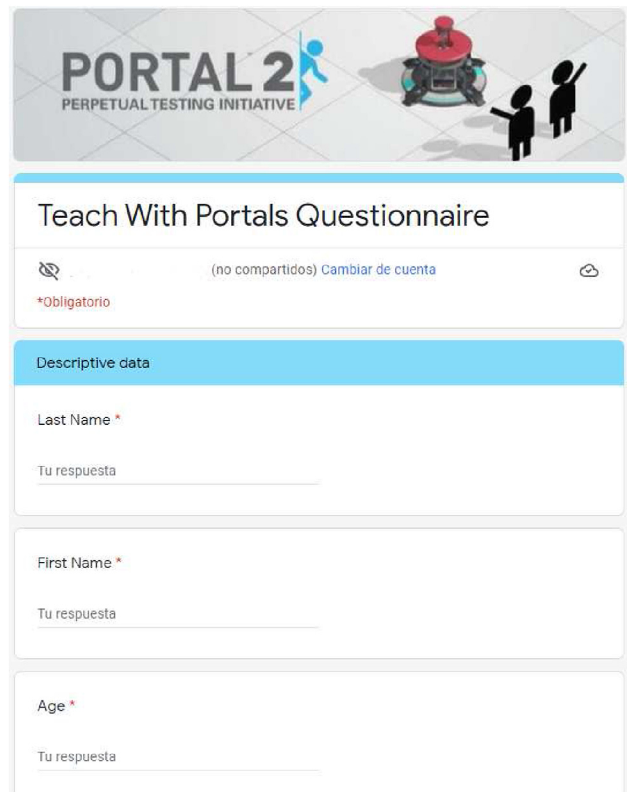

Figure 4. Screenshot of the Google Form Interface Presented to Students. Source: Own elaboration.

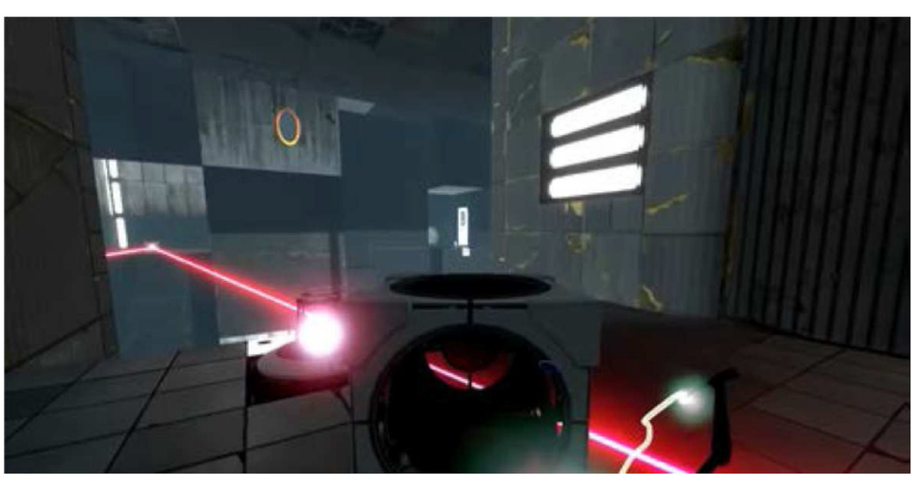

Figure 3. Example of a Level of the Portal 2 Video Game. Source: Own elaboration.

themselves to be video game players, 41 women (26%) and 5 men (55%) did consider themselves to be video game players. Only 6 women did not know where to place or how to define themselves. In light of these results, one might wonder whether we were introducing an added difficulty to our study, and whether this fact would invalidate the achievement of one of the objectives we had set ourselves. However, when observing the comments offered by the students, we saw that those who played video games on a regular basis did consider themselves to be video game players (see Figure 5). Although those who played sporadically did not consider themselves to be video game players, using a video game did not create any additional difficulty in identifying and mobilizing mathematical knowledge, nor did it pose a problem when considering potentially using the video game as a didactic tool in the classroom.

Why do the students play video games, and what are their main reasons for playing? The results in Figure 6 show that 140 (83%) students play mainly “For fun”, while 9 (5%) students play to “To relax”, 7 (4%) play “To spend time with friends”, another 7 (4%) “To distract myself” and the remaining 7 (4%) “To learn”. According to the data collected, students mainly play video games for recreational purposes. This factor is something to consider when identifying and mobilizing didactic-mathematical knowledge in the different activities presented to the students.

In principle, according to the answers given by the students in the previous question, it could be considered that video games represent a recreational object to the students, and are regarded this way by them when they expand on the reasons that lead them to play video games (see Figure 6). However, an educational potential can be seen to emerge (see Figure 7) with respect to the consideration of video games in the educational context. The number of individuals who believe that video games can be “considerably” educational is 62 (37%), while 7 (4%) believe them “sufficiently” educational, and 65 (38%) believe that video games can be “somewhat” educational. The majority of the students answered that video games range between “somewhat” and “considerably” educational. This may mean that they are aware of the usefulness of these tools as didactic resources to work on certain knowledge present in the curriculum of any subject. Among the students analyzed, 10 (6%) believe that video games are “not very” educational, and 26 (15%) believe that they are “not at all” applicable in the classroom for educational purposes.

In relation to the previous question, the students were asked to state their arguments for or against the use of video games in the classroom (see Figure 8). The possible arguments for their inclusion in the classroom include the following: 71 (42%) students said they facilitate and generate learning, followed by 29 (17%) students who highlighted their recreational nature, which is consistent in all questions, and 20 (12%) students who believe they promote creativity when mobilizing knowledge. Against the use of video games in the classroom, 31 (18%) students believe that video games generate violence and addiction, and 19 (11%) students believe that video games lack utility.

Focusing on the video game that is the subject of this study, Portal 2, we asked the students, after they had explored the game freely, whether they would use it in the classroom, and what educational level they thought it would be appropriate for. Figure 9 demonstrates that 149 (88%) students, the majority, consider it appropriate for use in the classroom, while 21 (12%) students do not consider it appropriate for use in the classroom.

Students were also asked to identify the educational level they believed the video game would be appropriate for. The majority, 79 (46%) students, stated the videogame was most appropriate for Primary Education, followed by 64 (38%) students who believed it was appropriate for Secondary Education. To a lesser extent, 12 (7%) students believed the video game was appropriate for University level, which is surprising considering the results obtained in the rest of the questions. Portal 2 was considered a suitable resource for Early Childhood Education by 8 (5%) students, 5 (3%) students believed it was appropriate for use in non-formal and informal learning contexts, and 2 (1%) students believed it was appropriate for vocational training. Although this question was not included in the form, we thought it appropriate to include because it shows that the students were able to internalize the mechanics and the potential skills that can be developed (see Figure 10).

The students were also asked how they would use this resource in the classroom (see Figure 11). Due to the fact that video games have not been created for educational purposes, it is the teacher's responsibility to direct and adapt their use in the educational context. The majority, 99 (58%) students, believed that the Portal 2 video game should be used as a supplementary resource for standard explanations and resources, as it can be used to provide a concrete explanation for concepts. Another large part of the sample, composed of 61 (36%) students, believes that its introduction should be anecdotal, as more of a playful motivation than a learning resource. Regarding the use of the video game as a main resource, 8 (5%) students consider it appropriate for some subjects related to mathematics and physics at different levels. Finally, 2 (1%) students believe that this resource is not useful in the classroom.

Throughout the article, we have mentioned the importance of constructing or designing motivating activities that arouse interest in the

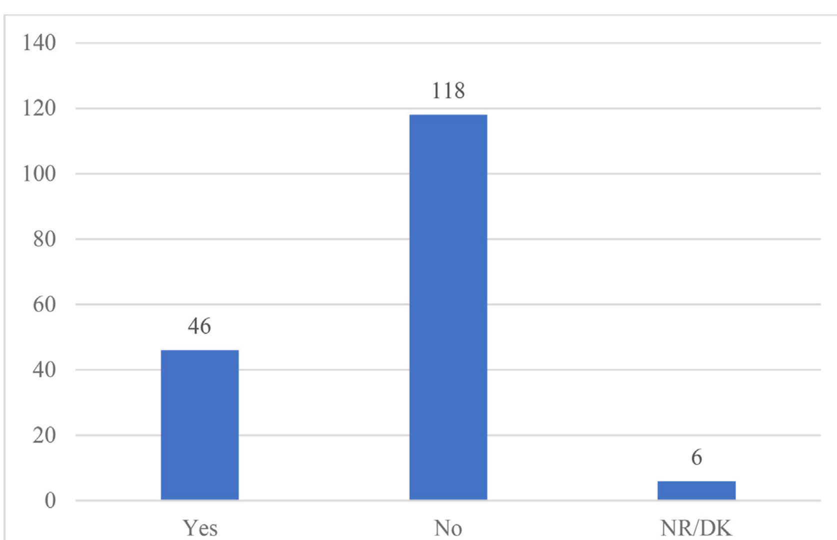

Figure 5. Are you a Video Game Player? Source: Own elaboration.

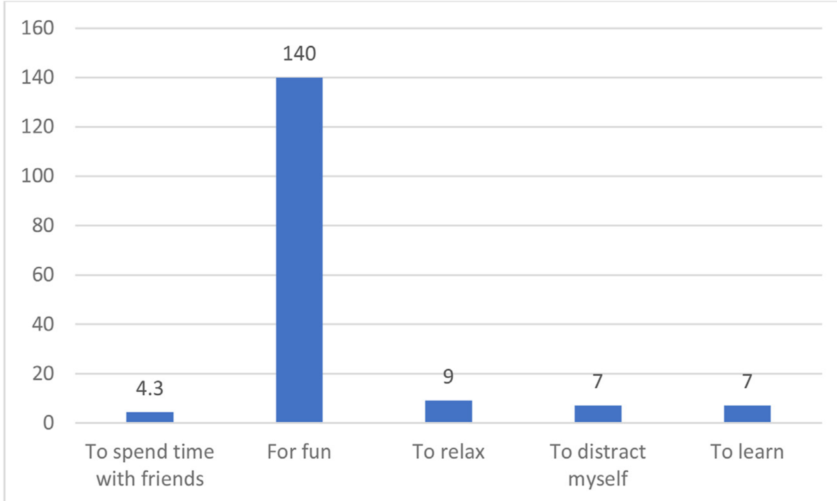

Figure 6. Reasons to Play Video Games. Source: Own elaboration.

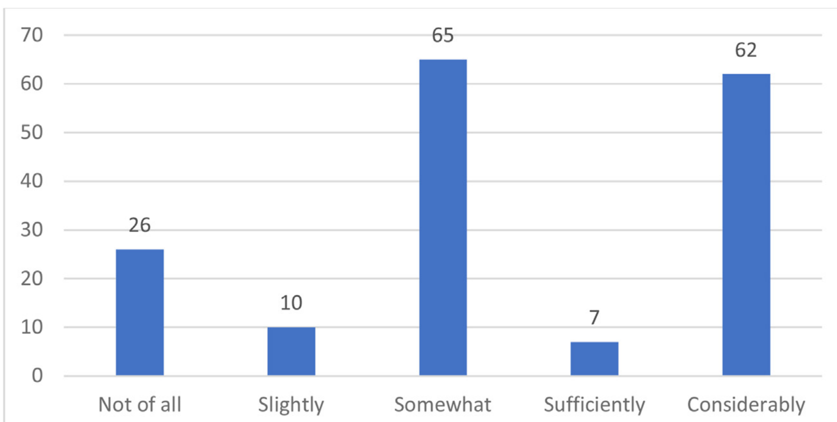

Figure 7. Perception of the Educational Possibilities of Video Games. Source: Own elaboration.

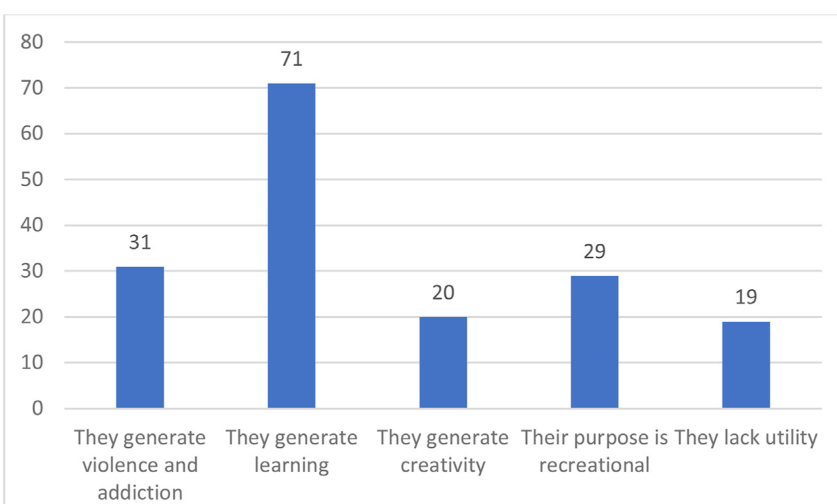

Figure 8. Arguments For or Against the Use of Video Games in the Classroom. Source: Own elaboration.

knowledge we intend to mobilize. To implement these motivational elements, it is necessary to be familiar with the tool and the elements it is composed of. One of the elements that becomes relevant as the game progresses is the narrative, which not only introduces the students to the protagonist's personal history but also helps them understand mathematical and physical concepts, both basic and advanced, and how these

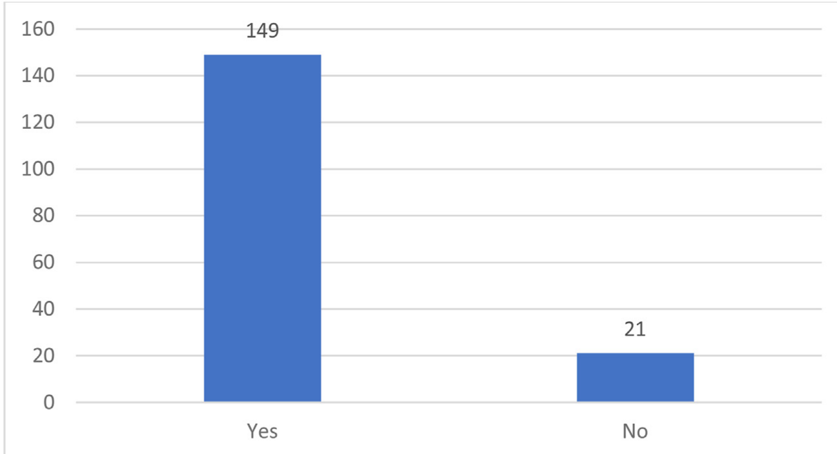

Figure 9. Would You Use the Portal 2 Video Game in the Classroom? Source: Own elaboration.

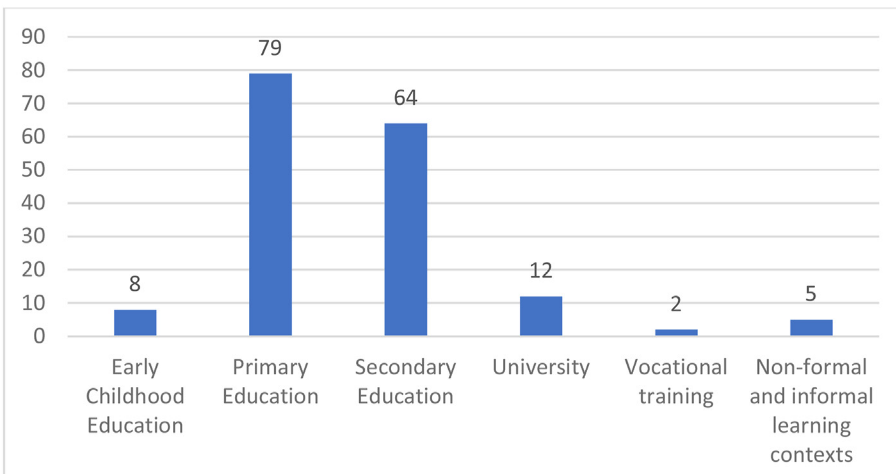

Figure 10. In Which Educational Level can the Portal 2 Video Game be Used? Source: Own elaboration.

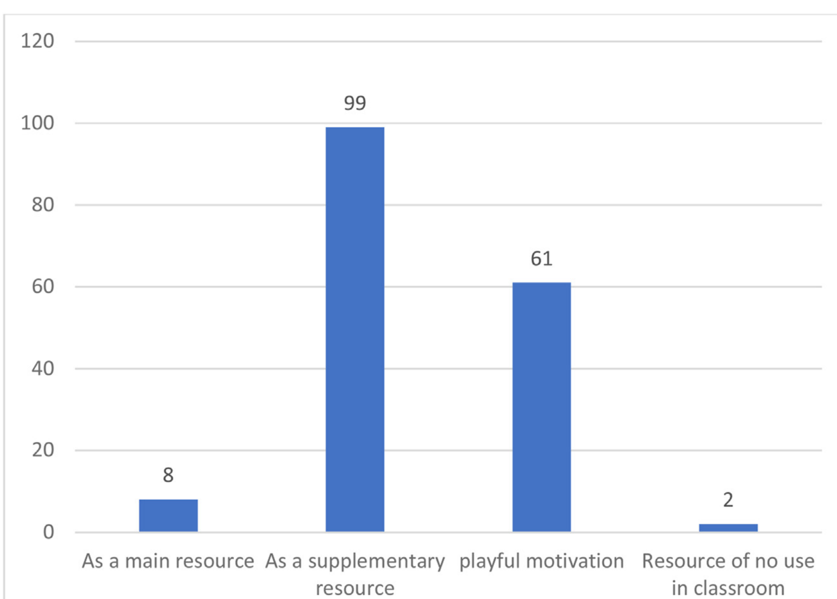

Figure 11. How Would you Introduce Portal 2 to the Classroom? Source: Own elaboration.

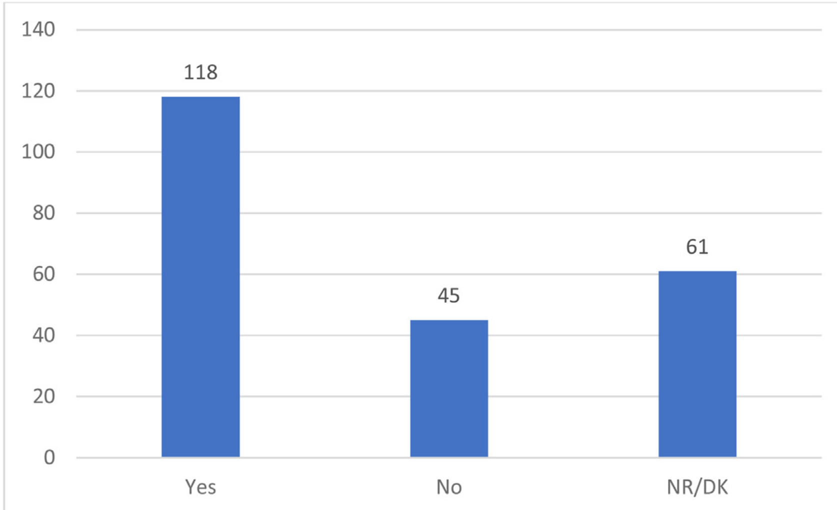

Figure 12. The Story Presented by the Video Game Matters. Source: Own elaboration.

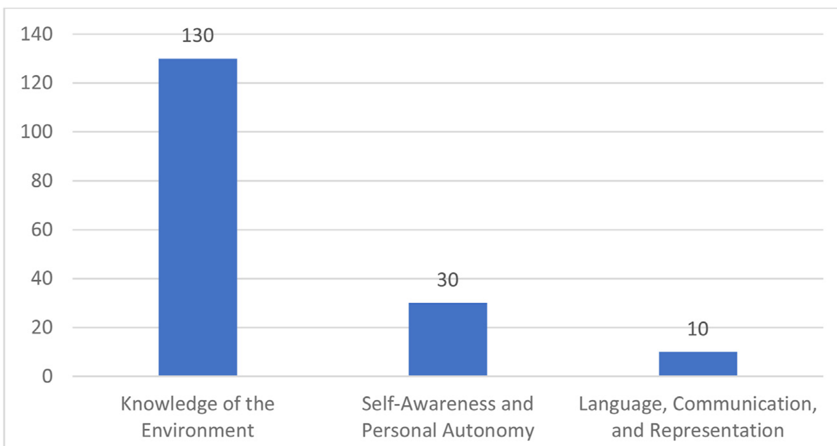

Figure 13. Areas of Knowledge of Early Childhood Education and their Possible Relationship with the Video Game. Source: Own elaboration.

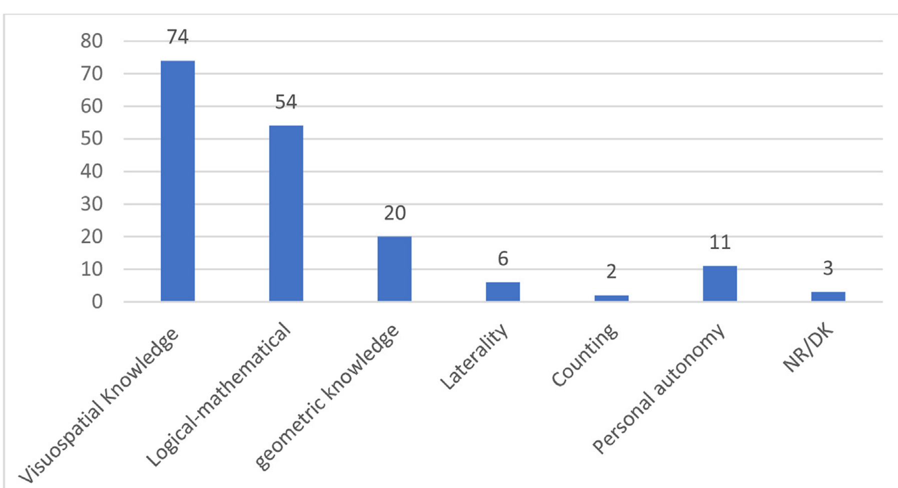

Figure 14. Knowledge that can be Mobilized by the Use of the Portal 2 Video Game. Source: Own elaboration.

significantly influence the progress of the story. This motivates the use of the resource, and even creates the need to examine and investigate the challenges that are proposed.

A large number of the participants (see Figure 12), 118 (69%) students, indicated that they found the narrative to be correct and suitable. Another group of the students, 45 (27%), believed that the narrative is neither suitable nor motivating enough to be used in the classroom. Finally, 7 (4%) students did not know or did not answer the question, although they did doubt its educational effectiveness. They were asked the reasons why they were attracted or not to the narrative and, interestingly, they answered that the game is too futuristic. Although some believe that this could be a motivating incentive, due to its visual and narrative appeal, others thought that this detachment from reality could complicate the students' understanding when solving the challenges posed in each level of the video game, as it is not something they can clearly experience in their daily lives.

As teachers undergoing initial teacher training in Early Childhood Education, the participants were asked to analyze, from their perspective, the areas in which the knowledge that is put to use in the video game could be included in Early Childhood Education (see Figure 13). The majority, 130 (76%) students, responded that it is related to the area of Knowledge of the Environment; due to the opportunities of the elements present in the video game to interact with the player, other NPCs (Non-Playable Characters), other elements, or the environment itself. The area of Self-Awareness and Personal Autonomy was selected by 30 (18%) students, as the constant requirement to overcome obstacles and challenges tests the players and encourages them to be decisive with scarce resources, which helps them overcome frustration and generates initiative in the face of challenges. The area of Language, Communication, and Representation was selected by 10 (6%) individuals; given the multiple commands available in the video game, signs, icons, and graphics could be used as help messages or complements to solve main obstacles, helping students understand how different communicative systems work.

One question regarding one of the specific objectives was related to the perception of learning linked to mathematics (see Figure 14); collecting the knowledge that the students considered to be mobilized and, therefore, that they identified as valid for the solution of different levels. The majority, 74 (43%) students, believed that the main knowledge that is put to use is visuospatial knowledge. This is due to the fact that in order to solve the levels, it is necessary to know where the exit door of the level is, how to get to it, and which elements in the space can be used to escape and complete the level. Another part of the students, 54 (32%), indicated that with this video game they mobilized logical-mathematical knowledge, and another 20 (12%) students perceived geometric knowledge when they played Portal 2. The promotion of personal autonomy by encouraging decision-making was also highlighted by 11 (6%) students. To a lesser extent, laterality was selected by 6 (4%) students, counting by 2 (1%) students, and 3 (2%) students either did not choose any option or were not able to perceive learning in the area of mathematics with the video game.

4. Conclusions

The present study's overall aim was to analyze the suitability of incorporating the Portal 2 video game into the subject Mathematical Knowledge in Early Childhood Education, according to the assessment of teachers undergoing initial teacher training. It should be pointed out that when proposing this study, the students felt uncertain about a resource that was not commonly used in their practices, and they did not believe it was educationally useful. In the responses obtained it can be seen that, although they were apprehensive of applying a video game in the classroom, one group were video game players and knew the mechanics of video games. The data shows that the students believed that video games were purely for recreational use, were to be used as a means of distracting themselves from daily life, or were simply to be used when spending some free time with friends, without losing the recreational part and with no other pretension; a consideration that has already been demonstrated in different studies and essays (Barr, 2017; Granic et al., 2014; McGonigal, 2010; Revuelta and Guerra, 2012; Steinkuehler and Squire, 2014).

As they experimented, by freely exploring the chosen video game, most participants saw the possibilities the video game offered as a teaching resource in the classroom (Barr, 2018; Gee, 2008; McGonigal, 2010). They were able to identify the mathematical knowledge that needs to be mobilized in order to pass each of the levels presented in the video game (Barr, 2017, 2018; Marín et al., 2019; Shute et al., 2015), and to frame them in the different areas of Early Childhood Education. Despite this, they specified at all times that the video game would be a good reinforcement resource to work on this knowledge, as indicated by López (2014), but not as the main tool. The results show that the Portal 2 video game is a didactic resource that a large part of the students recognize as useful in the educational context. It can be concluded that Portal 2 is perceived as a resource that promotes recreation by introducing concepts and content that is applicable to different disciplines of knowledge. Therefore, the video game can be introduced in the classroom and it is considered a valuable resource, but it must be approached methodologically in order to increase affinity with the students, and clear and achievable objectives must be set for the students; in this case, for educational purposes (Revuelta and Guerra, 2012). The students state that Portal 2 can be somewhat complex, so they designate it for use in Primary and Secondary Education, although they recognize that it can be used with infants if appropriately modified.

Addressing the specific objective: "To consider the inclusion of a video game as a motivating educational resource", the students perceived the introduction of the video game at early ages as a motivating element and related to the skills necessary for successful life and work performance (El Mawas, Bradford, Andrews, Pathak and Muntean, 2018), taking advantage of the capabilities that children at those ages have for new technologies, and using something recreational to achieve educational objectives (Gee, 2008; Revuelta and Guerra, 2012; Shute et al., 2015; Tost and Boira, 2015).

Each level introduces a new challenge that motivates the student to identify and mobilize the knowledge they possess or wish to develop to solve the level (Gee, 2008; Shute et al., 2015). The choice of a video game by students lies in the fact that it challenges them and that it makes them think; that is, it motivates them. McGonigal (2010) has already pointed out that players prefer games that challenge their abilities, since these motivate improvement and give them greater satisfaction in overcoming the imposed obstacles.

Addressing the specific objective: "To determine whether knowledge related to visuospatial perception is acquired through interaction with the Portal 2 video game", it can be noted that in the Portal 2 video game the main knowledge identified by students was related to the spatial-geometric domain (Adams et al., 2016; Pittman, 2013; Shute et al., 2015; Spence and Feng 2010; Ventura et al., 2013), although not to the detriment of the rest of the domains that make up logical-mathematical knowledge (Barr, 2017, 2018; Devlin, 2011; Bavelier et al., 2012; Shao et al., 2019). The knowledge mobilized when spatially structuring each video game level shows the acquisition of spatial perception.

This study has made it possible to successfully address the proposed objectives. However, it should be noted that this research is part of a larger project that intends to be replicated with students undergoing initial teacher training in the Early Childhood Education and Primary Education degree at other universities, to obtain a larger sample and to achieve a more precise definition of the results. It is also our intention to design a methodology for the use of the video game that could be carried out by teachers of both Early Childhood Education and Primary Education, which would later be implemented in Secondary Education. The existing limits of the research are also acknowledged, such as the need to use qualitative research tools to provide more information, as well as to use more sessions with specific and skill-oriented approaches, and the possibility of creating one's own levels in the video game.

Declarations

Author contribution statement

Jorge Guerra Antequera; Juan Antonio Antequera Barroso: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Francisco Ignacio Revuelta Domínguez: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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