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Enhancing adolescent reasoning skills through a video game program

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Abstract

Much research has been done on the benefits of video games in a physical education context (Camunas-Vega & Alcaide-Risoto, 2020; Fang et al., 2020). However, little attention has so far been paid to the effectiveness of commercial video games combined with actual basketball practice in helping students improve their reasoning skills (Chuang et al., 2021; Rogers et al., 2020). The study presents a quasi-experimental pre-post design with a control group in order to evaluate the impact of a specific training program in reasoning with the video game NBA 2K16. A convenience sample of 215 high school students participated in the study. Three reasoning subscales of the Evalua-9 psycho-pedagogical test (inductive $\alpha=0.88$; deductive $\alpha=0.85$; spatial $\alpha=0.89$) were used for data collection. Our findings show a significant moderate effect in the students who participated in the training program. An additional outcome was that sex differences in spatial and deductive reasoning in the pre-test disappeared in the post-test. We discuss the educational implications of the use of the video game as the main learning tool to enhance the reasoning process of Secondary Education students in Physical Education.

Keywords Physical Education · Improvement · Reasoning · Secondary education · Video games · STEM

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1 Introduction

Since their creation, video games have been considered leisure tools for the amusement and entertainment of players. During the last decades, video games have been introduced into teaching practice as tools to support knowledge acquisition. Various reviews of research on these practices provide considerable significant evidence of the potential of video games for the improvement of students' performance in physical activity (Fang et al., 2020; Ogawa et al., 2016); and not only for knowledge acquisition (Baradaran Rahimi & Kim, 2019; McLean & Griffiths, 2013) or to improve academic achievement (Camunas-Vega & Alcaide-Risoto, 2020). Acquiring knowledge and improving skills are basic aspects of the development of gameplay in video games, while video game-based learning seeks students to be active in their learning.

Nevertheless, Ferguson (2007) indicates that the uncontrolled and untrained use of video games can cause different types of harm to players. From the commercialization of the first video games to the present day, there has been concern about the time spent playing video games (Antar, 2022; Dorval & Pépin, 1986). In addition, excessive time spent in front of the television screen is a problem that affects the physical well-being of young people (Kracht et al., 2020). Consistent with this idea, excessive time spent playing video games has been associated with higher rates of attention problems in students (Swing et al., 2010), decreased sleep efficiency (Hisler et al., 2020), and reduced study time at home, and thus reduced academic performance (Abbasi et al., 2021).

To avoid all these problems, our research group believes that appropriate instructional techniques and strategies are essential. We carry out interventions and research projects in primary and secondary schools in which commercial video games are used as educational resources to work on curricular content, as well as to enhance the development of cognitive skills and abilities in students. As noted, video games have many benefits in both the educational and health fields. Commercial video games have been proven to be useful in the prevention, treatment, and rehabilitation of mental health problems such as depression and anxiety (Griffiths et al., 2013; Kowal et al., 2021). To this end, further research and dissemination of the results obtained are essential.

In this study, we assess if there is an improvement in the reasoning of high school students by combining the real game of basketball and the virtual game. The innovative nature of this research lies in the fact that it is one of the first programs made for adolescents to assess whether reasoning skills (deductive, inductive, and spatial) can be improved following sports training activities with commercial video games.

2 Theoretical framework: video games and reasoning

There are two major issues to address from a theoretical perspective in relation to this research: to show a model that allows us to adequately justify the learning processes that underlie the use of video games in the classroom; and to justify the potential of video games as a tool for learning and development of cognitive skills.

Regarding the learning processes, we would first like to highlight the versatility and adaptability of the use of video games to different pedagogical models and strategies (Squire & Jenkins, 2003).

Ëngestrom (1987, 2010) presents a model on the activity system concept and the expansive learning theory, useful to understand the learning processes that take place through the use of the video game. Ëngestrom and Sannino (2010) develop the relationships between subject, object, and instruments, where the object becomes learning outcomes with the help of the instruments (in this case, video games). Figure 1 shows an adaptation of this theory to our research.

According to the "expansive learning" approach, students engage in the construction and application of a new, broader, and more complex object and concept to perform their activity and they do so by activating and developing cognitive skills during the game. In our case, students had three main sources of information: the play experience, their informal knowledge and prior ideas about the content, and the objective knowledge provided in their classes. Once they had played in the classroom, these different sources of information were merged through the different activities proposed in the intervention. In this way, the students, supported by the video game, the teacher and their peers, can convert their previous concepts into learning outcomes and develop cognitive skills associated with the practices they are performing.

This development of cognitive skills and their potential as learning tools has been highlighted by authors such as Squire (2003), Squire and Jenkins (2003), Gee (2003; 2008), Salen and Zimmerman (2004), Jenkins (2006), Jenkins et al. (2006) or Prensky (2001; 2002). Beyond the ability of the video games to promote motivation (Prensky, 2001) and greater student involvement (Jenkins et al., 2006), authors such as Gee (2003) also emphasize their value as a digital literacy tool.

Regarding the development of thinking, video games add to the contents a structure of rules and dynamics that allows the development of inductive discovery skills, typical of the type of scientific thinking. This perspective involves encouraging the student's curiosity about his or her own environment, the formulation of questions or the ability to test hypotheses; in short, it is a matter of orienting and guiding towards exploration and understanding (Prensky, 2001). Video games encourage associative thinking through an iconic language, but, above all, they favour intuition and hypothetical thinking, since the player learns while playing, practicing, and deducing, activating his reasoning skills (Laniado and Pietra, 2005).

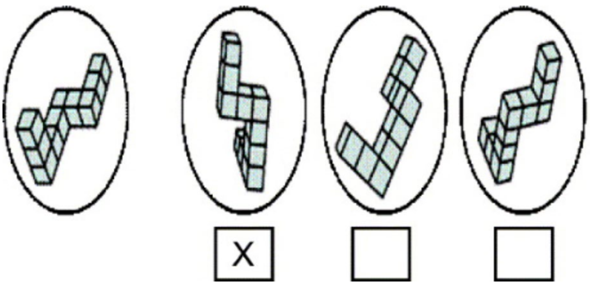

Fig. 1 An example item from the Vandenberg-Kuse Mental Rotation Test (Vandenberg & Kuse, 1978)

The benefits in the development of cognitive skills are also supported by Muras and Hernanz (2011) who show how the video game is useful in the classroom because its use can contribute to the development of (a) cognitive skills such as concentration, problem solving, analytical, strategic and planning capacity, development of logical and systematic thinking, deduction capacity, induction, memory development and linguistic ability; and (b) personal skills, such as self-esteem, personal autonomy, self-control and creativity.

In every video game, learning through reasoning is essential to advance and progress (Díez-Somavilla, 2016). However, before focusing on learning through reasoning, it is important to briefly address the different types of reasoning. In the following section, some research studies that examine the benefits of video games in the development of psychological processes will be presented, focusing on their incidence in the improvement of reasoning and physical education training.

2.1 Deductive reasoning

In logic, deductive reasoning represents an argument in which the conclusion is necessarily inferred from the premises (Sternberg et al., 2021). In its formal definition, a deduction obtains a finite sequence of formulas, of which the previous one is designated at the conclusion (the conclusion of the deduction). All the formulas in the sequence are either axioms, assumptions, or direct inferences from previous formulas using rules of inference. In short, it is to comprehend something based on an argument (Hillig & Müller, 2021).

According to Sternberg et al. (2021), deductive reasoning is carried out by following a series of logical steps. This logic allows us to refer to objects or phenomena and the laws that govern them; in the same way, it permits us to discover an unknown consequence, starting from a recognized principle (Cramer-Petersen et al., 2019). These principles are considered assumptions. An example is given below:

(1) All mammals have lungs.
(2) The dolphin is a mammal.
(3) The dolphin has lungs.

2.2 Inductive reasoning

Inductive reasoning involves concluding unknowns based on what we already know (Hayes & Heit, 2018). It is a type of reasoning in which the truthfulness of the premises just suggests the conclusion but does not guarantee it (Csapó, 2020). Inductive logic examines the methods for calculating the likelihood that a conclusion is accurate as well as the guidelines for creating strong inductive arguments. Inductive reasoning differs from deductive reasoning in that the former does not provide a conclusion as to when to accept an argument as true. Thus, the idea of "inductive force" is used, which describes the likelihood that a conclusion is unquestionably true when its underlying premises are true. Therefore, the term "inductive force" refers to the likelihood that a statement is true when all of its presumptions are true (Waschl & Burns, 2020).

A classic example of inductive reasoning is The Raven Paradox (Hempel & Oppenheim, 1945). To show the extent to which inductive logic can be counterintuitive, the paradox is as follows:

(1) All ravens are black. In the form of an implication, this can be expressed as: If something is a raven, then it is black.

By contrast, this statement is equivalent to:

(2) If something is not black, then it is not a raven.

The assertion “All crows are black” is validated any time we see a crow and confirm that it is black. Every black raven is an argument in favor of the proposition. Now, this proposition, according to Aristotelian logic, is equivalent to this other one: “All things not black are not crows”, so confirming the second one means confirming the first one (Huemer, 2018).

Deductive reasoning differs from inductive reasoning in that the latter has the benefit of being ampliative, meaning that the conclusion contains more information than the premises do. Because it is ampliative, inductive reasoning is frequently used in science and daily life (Huemer, 2018). However, given its fallacious nature, its justification is controversial. So, the following questions arise. Can inductive reasoning be used to conclude a limited sample? What differentiates an acceptable inductive argument from an unacceptable one? This causes problems in its validity and importance that have been maintained for centuries (Weber et al., 2020).

2.3 Spatial reasoning

The ability to envision and differentiate between various two-dimensional or three-dimensional objects is a component of spatial reasoning (Liao, 2017). It also includes the capacity to understand, control, and modify complex data and translate abstract ideas into specific thoughts (Shi et al., 2022).

According to Harris et al. (2021), spatial reasoning is crucial for solving everyday issues like using a map and compass, merging into heavy traffic, and navigating your surroundings. Determining the size of a box and the number of objects that will fit inside it are two further examples of tasks that need visual-spatial aptitude (Chen et al., 2019).

An illustration of a spatial reasoning test is shown in Fig. 2. The three comparison objects are on the right, while the target object is located far to the left. The comparison objects are the same shape as the target object but are given in several angular orientations, as indicated by the ticked box beneath one of them.

2.4 Psychological processes, video games, and physical education

Video games can be an ideal tool to enhance different cognitive aspects. Their use can improve self-confidence, as they provide mastery and control of learning. This is attractive to players because there are visual rewards when progressing through

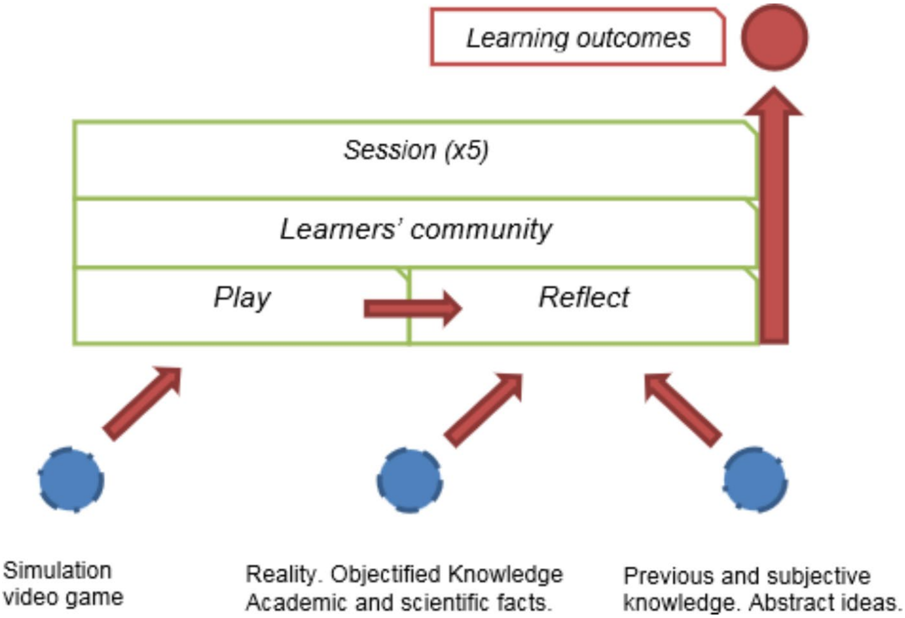

Fig. 2 Conceptual relation between elements present in the workshop and the learning outcomes. Source: Herrero and del Castillo (2013: *960)*

the game (Ahn et al., 2019). Similarly, video games generate self-esteem, since challenges must be overcome to progress in the game, something that requires accepting the mistakes that are made in the progress (Díez-Somavilla, 2016). For their part, Merino-Campos and del Castillo (2016) explain that active video games are an equally effective or even more appropriate learning tool than traditional learning instruments. Their success is based on the motivation that video games awaken among students (Barreto et al., 2017; Breien & Wasson, 2021; Kao, 2021). Video games rely on constant learning and can have alternatives to adapt to the learning capabilities of different players (Contreras et al., 2011). Besides, the difficulty of the game will be an important factor too. The greater the difficulty, the greater the challenge and reward for overcoming it. Therefore, this difficulty component will affect cognitive processes, as can be observed by oxygenated hemoglobin concentration signals in different regions of the brain (Yu et al., 2022).

Some studies show a better performance in reasoning using a video game as an educational instrument (Chuang et al., 2021; Iten et al., 2018; Mansor et al., 2020; Öztürk & Sarikaya, 2021). Similarly, research has confirmed the efficiency of video games in improving the reasoning of students (Alves Fernandes et al., 2016; Tan, 2021; Weger et al., 2015), considering that to progress in a video game, the development of reasoning is necessary to learn the game mechanics (Mansor et al., 2020).

This improvement in reasoning has an impact not only on the development of other cognitive skills but also on physical skills. When an athlete performs a basic skill, the body and mind work in coordination to achieve a positive result. To execute a technical action of a sport with precision, psychomotor skills are necessary. In addition, it has been proven that attention, information, working-memory capacity, information processing, and working-memory control are important aspects of sports performance (Vaughan & Laborde, 2021; Singh & Agashe, 2015) also concluded that reasoning ability influences the shooting skills of basketball players. Since field goal shooting speed in basketball requires a certain degree of motor coordination, basketball players with superior reasoning ability excel in field goal shooting speed as compared to players with inferior reasoning ability. Along the same line, Jukola (2019) also observed similar results in athletes. Furthermore, in the study by Hoyos et al. (2022), evidence was observed that there is a higher level of physical activity, metabolic equivalents (METs), oxygen consumption, motivation, and enjoyment when training while playing active video games. Similarly, Duman et al. (2016) elaborated an intervention proposal in which the basic material was a video game that required youth participation. At the end of the intervention, it was concluded that there were several benefits linked to the educational use of active video games, such as reduced obesity, increased self-concept, self-esteem, and social status in both sexes.

According to Lauer et al. (2019), Nazareth et al. (2019), and Newcombe (2020), there is considerable individual variation in the results of reasoning tests across a variety of experimental paradigms. One of the causes of such individual variation is the sex of the participants, which may be an important factor to be taken into account (Jansson et al., 2021; Preece & Bullingham, 2020). Numerous evidence suggests that boys have advantages over girls in spatial reasoning (Ahmadpoor & Shahab, 2019; Castro-Alonso & Jansen, 2019; Gagnon et al., 2018), deductive reasoning (Gelb et al., 2021), and inductive reasoning (Waschl & Burns, 2020). However, some studies show that there are no differences between deductive reasoning and inductive reasoning concerning sex (Burigat & Chittaro, 2007; Feng et al., 2007; Sokolowski et al., 2019).

From a similar perspective, the main aim of this study is to show the potential benefits of a program that includes the use of a video game as the main learning tool for students' reasoning in three of its dimensions: deductive, inductive, and spatial. In addition, it aims to investigate whether there are aspects of reasoning that differ between students who were exposed to the intervention and those who were not, and to analyze possible differences by gender.

3 Materials and Methods

3.1 Participants

The methodology of this research is based in a quasi-experimental design. Convenience sampling was the sampling method. Units are selected for inclusion in the sample due to geographical proximity and willingness to participate in the research of the school managers, families, and students.

The sample of students (n = 215) belonged to 3º Grade of a a secondary school in Alcalá de Henares, at the Community of Madrid (Spain). They have an average age of 15 years, with 110 girls (51.16%) and 105 boys (48.84%). The sample is composed of eight class groups of students, of which five were assigned to the experimental

Table 1 Distribution of students in the control and experimental groups

Group		Girls	Boys	Total
Experimental	n	72	69	141
	% total	33.49%	32.09%	65.58%
Control	n	38	36	74
	% total	17.67%	16.74%	34.42%
Total	n	110	105	215
	% total	51.16%	48.84%	100%

condition and the other three to the control condition. 141 participants (65.58%) were assigned to the experimental group, and 74 participants (34.42%) to the control group (Table 1).

The experimental group performed a specific training program for nine weeks, once a week, 60 min per session. During the first 30 min, the students played the *NBA 2K16* video game. Subsequently, in the other 30 min of the session, active basketball exercises were performed about what they had practiced in the video game.

The students in the control group did not receive any structured video game program during the intervention. They performed the basketball activities as part of their standard curriculum in the 60-minute physical activity sessions of the Physical Education subject.

3.2 Instruments

3.2.1 Reasoning test

The results before and after the intervention were measured with the reasoning subtest of the *Batería psicopedagógica Evalúa-9* (García-Vidal et al., 2000). The reasoning scale consists of three independent tests, aimed at inductive, deductive, and spatial reasoning. The application was made by a single researcher, trained in the use of this instrument, and the application time was 40 min for each student.

The inductive reasoning test assesses the ability to operate with concepts and consists of six tasks: identifying a set of elements that do not meet a characteristic; recognition of a severer category that includes the elements of a given set; completing verbal analogies; continuing symbolic series; completing figurative analogies and continuing figurative series. Figure 3 shows some exercises of inductive reasoning. The English translation of the task instruction is the following: *4th Task. Mark with an X the element that follows in the series. Look at the example.*

The spatial reasoning test assesses the student's ability to operate with spatial models, identifying elements that are part of a global structure, and consists of two tasks: to identify, in a set of Kohs cubes, the elements that are not part of an overall

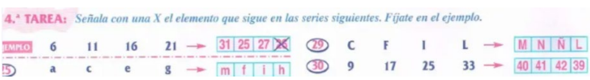

Fig. 3 Example inductive reasoning exercises from Batería psicopedagógica Evalúa-9 (García-Vidal et al., 2000)

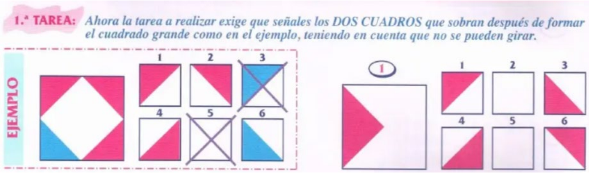

Fig. 4 Example spatial reasoning exercises from Batería psicopedagógica Evalúa-9 (García-Vidal et al., 2000)

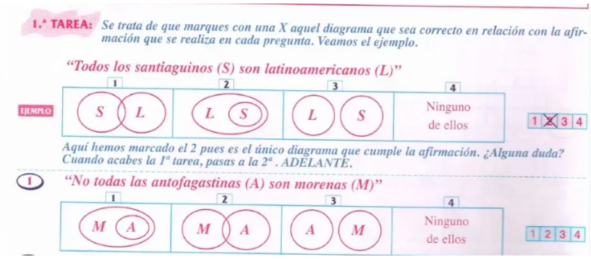

Fig. 5 Example deductive reasoning exercises from Batería psicopedagógica Evalúa-9 (García-Vidal et al., 2000)

spatial structure and to identify the solid figure that is formed from an unfolded spatial structure. Figure 4 shows some exercises of spatial reasoning. The English translation of the task instruction is the following: *1st Task. Now the task to be performed requires you to point out the TWO SQUARES that are left over after forming the large square as in the example, bearing in mind that it cannot be rotated.*

Finally, the deductive reasoning test assesses the ability to operate with categories and consists of two tasks: to identify a diagram that represents a given proposition and to identify categories that appear related in a Venn diagram. Figure 5 shows some exercises of deductive reasoning. The English translation of the task instruction is the following: *1st Task. You have to mark with an X the diagram that is correct about the statement made in each question. Let's see the example. "All Santiaguiños (S) are Latin Americans (L)" Here we have marked 2 because it is the only diagram that fulfills the statement. Any doubts? When you finish the first task, you can move on to the second one. Go ahead.*

The instrument facilitates the construction of a centile score for each of the subscales. In addition, the instrument has been positively evaluated by the General Council of Official Colleges of Psychologists both for its content and construct validity, and for its reliability (Romero Tarazona, 2017). The instrument underwent pilot testing and index correlation to demonstrate validity and reliability. The internal consistency of the *Batería psicopedagógica Evalúa-9* is excellent in the three inductive ($\alpha = 0.88$) spatial ($\alpha = 0.89$) and deductive subscales ($\alpha = 0.85$).

3.2.2 NBA 2K16

To execute the training program, the video game *NBA 2K16* was introduced into the classroom. It is a basketball video game for the PlayStation 3, PlayStation 4, Xbox 360, Xbox One, Microsoft Windows, Android, and iOS that was created by Visual Concepts and distributed by 2 K Sports. It was released on 29 September 2015.

This video game allows you to have the experience of becoming a professional basketball player in the NBA and perform all the individual technical actions. The students were equally able to experience being the coach, setting up the tactical moves that the team will later make during the game. Therefore, this experience allows players to experience, in a virtual environment, an action that can be brought to reality thanks to the model visualized and internalized by the students (Rogers et al., 2020). Also, this video game included women's teams and athlete avatars to increase diversity and representation (Darvin et al., 2021). In addition, to improve in the game, they must use their reasoning skills (Contreras et al., 2011).

The choice of the video game used in the experimental group was appropriate for the age of the students. The age rating used in Europe (Pan European Game Information, PEGI) helps to know if the video game is suitable for the age of the child who will use it (Felini, 2015). In this case, the *NBA 2K16* video game has a PEGI 3 rating, which means that it is suitable for players over the age of 3. Also, for the Entertainment Software Rating Board (ESRB), which is used in the three major countries of North America - Canada, Mexico, and the United States, *NBA 2K16* has an E. This means everyone can play it. Another reason was the motivation it generates in students. Sport-based video games, such as FIFA 17 or Madden NFL, or NBA 2 K are the favorite games without violence for adolescents (Funk et al., 2018). This motivation generates a greater predisposition to use them (Breien & Wasson, 2021; Kao, 2021).

3.3 Procedure

The study used a quasi-experimental approach with repeated pretest/posttest measurements with a control group. It agreed to the moral standards necessary for conducting human subjects research (informed consent, right to information, protection of personal data, guarantees of confidentiality, non-discrimination, free of charge, and the possibility of abandoning the study in any of its phases).

The study was conducted in three phases. The first was the planning phase. Then, the gaming phase included a training program that took place from February to April in the following nine weeks. Finally, the analysis phase, where the training program results were evaluated.

3.3.1 Planning phase

The beginning of this phase was conducted by the researchers before going to school. After analyzing previous studies on reasoning, two hypotheses were proposed for this study:

1. Students in the experimental group will achieve better results in reasoning after completing the video game intervention than those in the control group.
2. Within the experimental group, boys will outperform girls in improving spatial reasoning after the intervention.

Once the two hypotheses had been put forward, to conclude this initial phase an interview was held with the director and the teachers of the school. In this interview, the project and the work scheme were explained; also, we requested the teachers' collaboration. Parental permission forms and student assent forms regarding participation in the study were collected before gathering data.

3.3.2 Gaming phase

Pretests were conducted one week before the first session of the gaming phase. All students were provided uniform instructions, and all questions were read aloud by a research assistant.

After performing the test, the experimental group performed a specific training program for nine weeks, as detailed in the participants' section. The objective of each session can be seen in Fig. 6. The control group performed the traditional basketball classes.

After the intervention, in the post-test phase, the aforesaid instruments were administered to the experimental and control groups as in the pretest. All data collection was videotaped and analyzed by trained researchers by the aforementioned procedures.

3.3.3 Analysis phase

The data were analyzed with SPSS statistical software, v. 25.0. A confidence level of 5% was established for all tests ($p < .05$). As a first step, the sample was subjected to the Kolmogorov-Smirnov test as part of the "goodness of fit" procedure. This gauges how closely our data set's distribution resembles that of a normal distribution.

Once the test was carried out, its effectiveness was evaluated by Levene's test (Levene, 1961), which was used to determine if our sample was normal for each of the dependent variables and if there were equal variances in the samples under study, both tests were conducted on the experimental group and the control group, in the

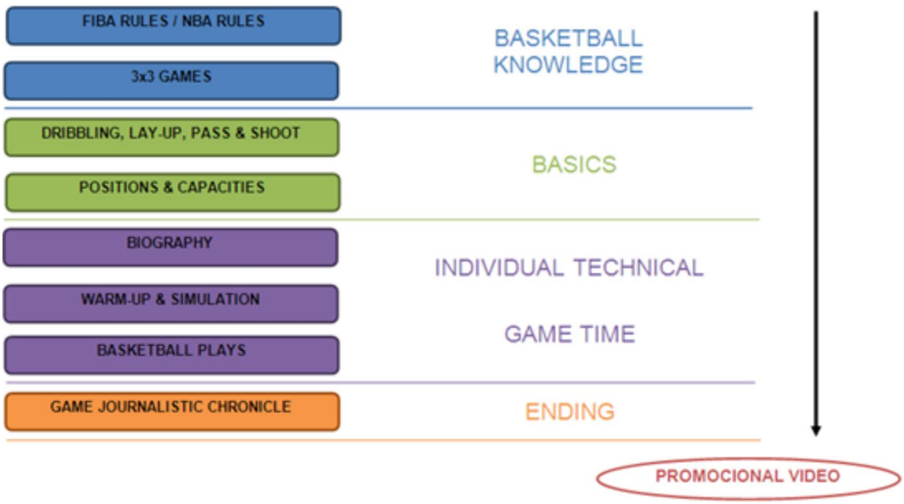

Fig. 6 Objectives of the training program

pre-test and the post-test, for all the dependent variables. Statistical analysis of the data was conducted by applying the parametric Student's t-test.

4 Results

In order to determine the effects of the program, first of all, the following analyses were conducted: (a) descriptive analysis for both the pre-test and post-test periods are presented for the experimental group and the control group: inductive reasoning, deductive reasoning, and spatial reasoning, as well as for the researched dependent variables, the means, and the standard deviation; (b) the differences between the means of the two groups (experimental and control) in the findings obtained; (c) sex differences between groups.

The descriptive analysis shows a positive increase between the pre and post-test in the experimental group (Table 2). In inductive reasoning, the experimental group experiences a positive change of 0.857, in deductive reasoning, the change is 0.998 and in spatial reasoning, we found the highest variation (1.557).

Considering the results from the application of the Kolmogorov-Smirnov test (Kolmogorov, 1933), the six variables analyzed are distributed normally ($p > .05$), so all of them will be considered when checking the difference in means (Table 3).

Table 2 Descriptive data

	Experimental (n=141)		Control (n=74)	
	Mean	SD	Mean	SD
Inductive Reasoning Pretest	18.37	3.76	18.99	3.88
Inductive Reasoning Post-test	19.24	4.03	18.98	2.96
Deductive Reasoning Pretest	10.62	4.61	11.22	4.31
Deductive Reasoning Post-test	11.62	3.86	10.92	3.08
Spatial Reasoning Pretest	14.55	4.40	15.24	4.20
Spatial Reasoning Post-test	16.10	4.58	15.44	3.57

Table 3 Normality test

		Z	n	p
Inductive Reasoning Pretest	Experimental	0.054	141	0.200*
	Control	0.050	74	0.200*
Inductive Reasoning Post-test	Experimental	0.058	141	0.200*
	Control	0.054	74	0.200*
Deductive Reasoning Pretest	Experimental	0.069	141	0.099
	Control	0.063	74	0.200*
Deductive Reasoning Post-test	Experimental	0.058	141	0.200*
	Control	0.085	74	0.200*
Spatial Reasoning Pretest	Experimental	0.066	141	0.200*
	Control	0.121	74	0.070
Spatial Reasoning Post-test	Experimental	0.062	141	0.200*
	Control	0.074	74	0.200*

Table 4 Equality of variances

	Levene	p
Inductive Reasoning Pretest	0.367	0.545
Inductive Reasoning Post-test	3.098	0.080
Deductive Reasoning Pretest	0.836	0.361
Deductive Reasoning Post-test	1.763	0.186
Spatial Reasoning Pretest	0.422	0.517
Spatial Reasoning Post-test	3.826	0.052

Table 5 T Student for independent samples (pretest)

	t	p	Mean dif.
Inductive Reasoning Pretest	0.105	0.917	0.083
Deductive Reasoning Pretest	−0.392	0.695	−0.350
Spatial Reasoning Pretest	−0.415	0.679	−0.358

Table 6 T Student for related samples (experimental group)

		Mean	SD	p
Experimental group	Inductive Reasoning	0.875	3.565	0.024
	Deductive Reasoning	0.998	3.664	0.012
	Spatial Reasoning	1.557	3.150	0.001
Control group	Inductive Reasoning	0.015	2.070	0.509
	Deductive Reasoning	0.301	2.392	0.283
	Spatial Reasoning	0.097	1.874	0.369

For this sample, all the variables that had previously met the normality assumption had equal variances (Table 4).

To analyze the inter-group and intra-group differences T-Test for independent and related samples were calculated. These analyses allowed us to validate (a) that there were no statistically significant differences between the mean scores of the groups between the results of the pretest by determining whether there were differences between the means of the two groups (experimental and control) in the findings obtained, and (b) to confirm statistically significant differences (and effect size) between the subject's scores in the reasoning variables (dependent variables) in each group considering the administration of the tests before the intervention (pretest) and afterward (post-test).

As shown in Table 5, the starting situation of the control group is remarkably similar to the experimental group in the three variables studied ($p>.05$).

Regarding intra-group differences, the findings demonstrate that the experimental group's outcomes are statistically significant for the three variables examined (Table 6). The mean difference for the variable Spatial reasoning is higher (1.557, $p=.001$) than for the variables inductive (0.875, $p=.024$) and deductive (0.998, $p=.012$) reasoning. When the control group was examined, the results did not show statistically significant differences between the pre and post-test in the variables studied (Table 6).

The effect size is finally determined for the three variables within the experimental group following Hunter and Schmidt (2004) (Table 7). Quantifying the success of a specific intervention about comparison is a particularly useful application of spa-

Table 7 Effect size (experimental group)

Inductive Reasoning	Cohen's d	0.292
	Hedges correction	0.291
Deductive Reasoning	Cohen's d	0.314
	Hedges correction	0.313
Spatial Reasoning	Cohen's d	0.475
	Hedges correction	0.474

Table 8 T Student for related samples and effect size according to sex (experimental group)

		Mean	SD	t	p	Cohen's d	Hedges correction
Girls (n=72)	Inductive Reasoning	0.693	4.227	1.158	0.169	0.164	0.163
	Deductive Reasoning	0.918	4.476	1.679	0.046	0.205	0.204
	Spatial Reasoning	1.424	4.944	2.798	0.017	0.488	0.486
Boys (n=69)	Inductive Reasoning	1.066	4.917	1.831	0.076	0.217	0.216
	Deductive Reasoning	1.081	4.885	1.152	0.070	0.221	0.220
	Spatial Reasoning	1.695	3.146	3.771	0.001	0.539	0.536

tial reasoning. The intervention had a greater influence than the other factors in this sample because of the intervention's effect size of 0.474.

Analyzing these dimensions in Table 8 according to sex, our findings show statistically significant differences in spatial reasoning in both sexes with moderate effect sizes (Girls $p=.017$; Boys $p=.001$) and deductive reasoning in the case of girls ($p=.046$), but with a lower effect size ($p=.204$).

5 Discussion

As stated above, recent research has suggested a relationship between playing sports video games, even for brief periods, and improvements in a variety of cognitive skills (Baradaran Rahimi & Kim, 2019; McLean & Griffiths, 2013). In addition to replicating and extending these results, this research examined the effects of video game practice on reasoning skills tasks and has been done specifically for activities related to basketball practice.

The objective of improvement that was proposed at the beginning has been demonstrated with the results obtained, both comparing the group itself before and after the intervention and comparing the experimental group with the control group. It is equally relevant that, as seen in previous research, our findings show how a brief period of immersive play with video games leads to an improvement in the reasoning of individuals in line with what previous research indicates (Chuang et al., 2021; Iten et al., 2018; Mansor et al., 2020; Öztürk & Sarikaya, 2021).

In numerous tasks, the experimental group has achieved benefits in deductive and spatial reasoning, when their results are compared with those of the control group. In particular, the students of the experimental group showed significant improvements in tasks measuring spatial skills and operating with categories. When the intragroup data of the experimental group are analyzed, comparing the pretest and post-test results, it is verified that there is an improvement in deductive and spatial reasoning.

This validates the theory that the efficient use of video games is beneficial for the reasoning of the players (Alves Fernandes et al., 2016; Tan, 2021; Weger et al., 2015).

Concerning the sex variable, the results obtained contradict the hypothesis formulated in the planning phase (Ahmadpoor & Shahab, 2019; Castro-Alonso & Jansen, 2019; Gagnon et al., 2018). This hypothesis was based on recent meta-analyses on the development of sex differences in mental rotation by Lauer et al. (2019), navigation skills by Nazareth et al. (2019), and spatial puzzle solving by Newcombe (2020) that indicated a small to moderate boys' advantage. However, our program has achieved an extremely positive aspect which is to obtain a more considerable improvement in the spatial reasoning of girls compared to their boys' peers, despite what the previously cited recent meta-analyses on the development of sex differences indicate and other research on reasoning and sex difference previously mentioned (Ahmadpoor & Shahab, 2019; Castro-Alonso & Jansen, 2019; Gagnon et al., 2018; Gelb et al., 2021; Waschl & Burns, 2020). These positive results are the minority, but they have been obtained in other studies such as the research on navigation in 3D virtual environments by Burigat and Chittaro (2007) or Feng et al. (2007) and mental rotation training by Rodán et al. (2016). These studies indicated that playing action video games reduced the sex difference in spatial cognition, but girls did not outperform boys, as was the case in this research. This could be explained due to the motivation generated in the girls by playing video games (Barreto et al., 2017; Breien & Wasson, 2021; Kao, 2021). This makes them more interested in the game, the sport, and the rules, which helps them to perform better than when they do physical activity.

Some educational implications emerge from this study. Much of the literature on sex differences in the field of educational sciences has focused on differences in the rates of children who prefer teaching paths leading to science, technology, engineering, and mathematics (STEM) disciplines (Rodán et al., 2016). Spatial reasoning is critical to success in, among others, STEM disciplines (Vossen et al., 2020). Since spatial skills are positively correlated with standardized test scores, motivation for learning, STEM major declaration, and several science courses taken (Gold et al., 2018; Mouronte-López et al., 2021). This study suggests that training these skills in secondary education could increase the potential pool of students who successfully enter STEM careers. Consequently, it is becoming increasingly necessary to investigate the use of sports video games to see if there is a process of reasoning from what is learned in the video game to the actual practice of the sport.

6 Conclusion

This research has focused on proving the benefits of the proper use of video games to achieve an improvement in the student's reasoning. As already mentioned in the previous section, the objective of improvement has been demonstrated by the results obtained both by comparing the group itself before and after the intervention and comparing the experimental group with the control group.

In addition, satisfactory results have been obtained in the improvement of spatial and deductive reasoning in girls compared to boys. Sex differences in the spatial and deductive reasoning on the pretest disappeared on the post-test. The reason for this improvement could be due to the use of the video game as a pedagogical instrument because it helps to a better understanding of spatial reasoning than traditional learning and increases girls' motivation.

It is important to emphasize that this study is one of the first investigations in adolescents that analyzes the degree of improvement offered by sports training with commercial sports video games in various types of reasoning (deductive, inductive, and spatial). The results presented demonstrate that reasoning ability could be improved with this alternative instrument.

Future studies in this field can be guided by these findings, but it is vital to keep in mind that, because of their quasi-experimental design, they cannot be used to draw causal inferences. The results should also be regarded as preliminary due to the small sample size and hence weak statistical power. As a result, our findings are meant to encourage empirical analysis in subsequent studies. This study adds to the body of knowledge by pointing out the advantages of exercise for cognitive abilities.

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Declarations

Competing Interest The authors have declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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