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# Do Video Games Improve Spatial Abilities of Engineering Students?*

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*This paper analyses the relations between the spatial abilities of first year engineering students and the use of certain types of video games. The study was carried out with Mechanical, Electronic and Civil Engineering students at the University of La Laguna (Spain) during the 2007/2008 academic year. An intensive training course on spatial abilities was conducted, using only video games as a learning tool. The video games were used on two different platforms: personal computers (PC) and handheld video games consoles (Nintendo DS). This console was chosen as it was the only one that offered the possibility of playing interactively with the screen, using an electronic pencil. The game chosen was Tetris because there is a PC and a Nintendo version, and it requires spatial abilities to play. Spatial abilities were measured by two tests: the MRT and the DAT: SR. From the results obtained, we can conclude that video games are a good strategy for improving spatial abilities.*

**Keywords:** spatial abilities; video games; MRT; DAT: SR; electronic pencil, Tetris

## INTRODUCTION

THE USE OF VIDEO GAMES to improve spatial abilities has been related by several authors [1– 4], however, no reference has been found to any specific study conducted in Engineering Graphics at Engineering Schools at University level.

We had specific data about the use of video games in engineering students at the University of La Laguna (Tenerife, Spain). These data were collected at the beginning of the academic year 2004/05 as part of Saorín's Ph.D. thesis [5]. The spatial abilities of students starting the first year of an engineering degree at this University were measured with two tests: MRT (Mental Rotation Test) and DAT: SR (Differential Aptitude Test, Spatial Relation) [6].

Measurements were taken of 460 students, who were also asked to fill in a data questionnaire with information on 20 aspects that could be related to spatial abilities, such as: age, sex, education, hobbies, sports played, whether or not they were regular video game players, etc. Owing to the breadth of the aspects covered in this questionnaire, the concept of what was considered a regular video games player was never precisely defined. For this reason, each student classified him/herself as a regular player or not, based on his/her own criteria.

The data obtained in the Saorín's study were processed using a multi-variant regression that identified the use of video games as a significant variable within the set of aspects studied (this is especially true when referring to the MRT test). The general conclusions concerning video games drawn from this initial study [5] are listed below.

- Regular use of video games enables students to get better results in the spatial abilities tests (especially in Mental Rotation).
- The percentage of female non-players is noticeably higher than the percentage of non-playing men.
- Players, be they men or women, obtain higher than average scores for their sex in the tests and higher scores than non-players.
- The worst results are obtained by non-playing women.

These conclusions obviously have to be taken with certain reservations, bearing in mind that the data concerning the condition of regular user of video games was obtained on the basis of the criteria of the subject taking part in the study.

In this paper, we will attempt to clarify the status of regular video game user with a new data survey.

On the other hand, not all the video games are equal. Some authors have used the 'Tetris' video game as a tool to improve spatial abilities [1, 7], as was the case in this experience. These studies were conducted in the field of psychology, focusing on the effects caused during adolescence and related to gender. More recent works [8] claim that training with action games develops spatial skills, benefiting women to a greater extent than men.

In the next sections, the question of whether

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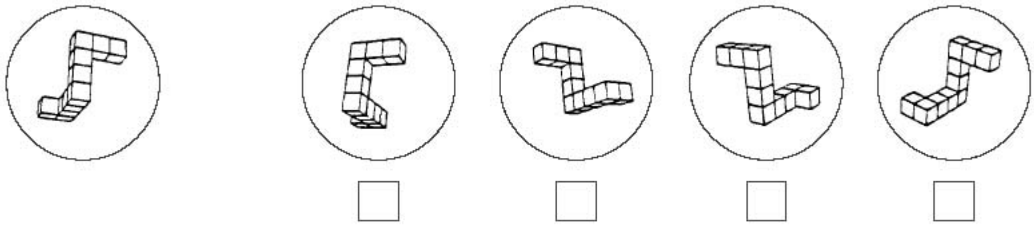

Fig. 1. Example of MRT test question.

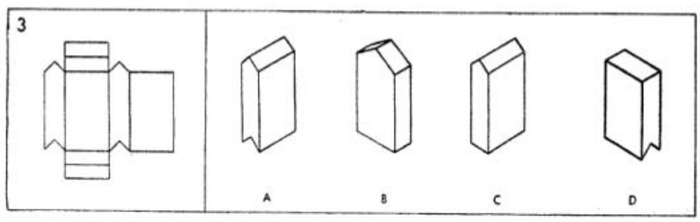


Fig. 2. Examples of DAT.SR test questions.

video games can improve the spatial skills of engineering students will be analysed. First a summary is given of the components of spatial skills and the tools to measure them, and then a pilot study based on training with video games are described in detail, along with the remedial course and a statistical analysis of the results. The paper ends with the presentation of the conclusions reached from this experience and with some proposals for future work.

## MEASUREMENT OF SPATIAL ABILITIES AND TRAINING METHODS

There can be no doubt that spatial ability is one of the components of human intelligence as this is backed by countless lines of research [9–14]. There is not, however, any clear agreement on the subskills that this component is made up of. McGee [15] distinguishes five components of spatial skills: Spatial Perception, Spatial Visualisation, Mental Rotation, Mental Relation and Spatial Orientation. Some of the most widely accepted theories are in the paper by Lohman [11] and the Meta-analysis conducted by Linn and Petersen [16]. This identifies three kinds of spatial skills: *Spatial Perception*, which requires participants to locate the horizontal or the vertical in a stationary display while ignoring distracting information. *Mental Rotation* involves the ability to imagine how objects will appear when they are rotated in two or three-dimensional space. *Spatial Visualisation* refers to the ability to manipulate complex spatial information when several stages are needed to produce the correct solution.

Halpern and LaMay [17] added two other distinct types: *Spatial-Temporal Ability* and the *Generation and Maintenance of a Spatial Image*. The former involves judgments about the responses to dynamic or moving visual displays, and the latter requires participants to generate an image such as the shape of a particular letter of the alphabet, and then use the information in the image to perform a specified cognitive task. Researchers from the fields of psychology [18] and geometry [19] simplify this classification into two components:

1. **Spatial Relation—**The ability to imagine rotations of 2D and 3D objects as a whole body
2. **Spatial Visualisation—**The ability to imagine rotations of objects or their parts in three spatial dimensions by folding and unfolding.

There are a large number of tools available for measuring spatial abilities [20–24]. Using this latter classification, we chose two tests, one for each of the main categories outlined above, to enable us to quantify the values of the spatial ability:

1. the Mental Rotation Test (MRT) for spatial relations [20];
2. the Differential Aptitude Test—Spatial Relations Subset (DAT: SR) for spatial visualisation [21].

Differences in spatial skills between men and women have been studied in many studies, which suggest that men have the edge over women in mental rotation tasks [16, 25, 26].

On the other hand, some authors have suggested that these differences may be influenced by the different social status of the people concerned [27, 28], or by environmental and socio-cultural aspects [29]. A knowledge of the relation between the regular tasks that men and women carry out and spatial abilities would therefore be a good indicator. Some studies done along these lines [8, 30] conclude that video games may be a tool to improve these abilities.

Spatial skills can improve with specific training. The methodologies used may differ, depending on the area of application (pen and paper sketches, isometric sketching, multi-media platforms, on-line platforms, video games, virtual reality, augmented reality, specific software, physical materials, etc.). Contents such as descriptive geometry, orthographic views, three-dimensional modelling, etc. have been used in engineering in order to improve the spatial abilities of students. Dejong [31], Lord [32], Sorby [33, 34] and Alias *et al.* [35] used a traditional graphics course on sketching activities, orthographic projection, isometric drawing. In his work, Wiley [36] concluded that 3D solid models and animation may help in developing visual perception abilities. Devon *et al.* [37], demonstrate that solid modelling increases the student's visualisation scores much more than using 2D CAD. In recent studies, Martin-Dorta *et al.* [38], compare the effect of several different methodologies for improving spatial abilities and they show that the Google Sketch Up software is an optimum tool to be included in these methodologies. Dünser *et al.* [39] conclude that augmented reality is a highly useful tool for training spatial abilities. Rafi *et al.* [40] demonstrate the effect of virtual reality based training on improving the spatial abilities of men and women.

## PILOT STUDY

*Rationale*

The development of spatial abilities in engineering students is directly related to the professional success of their work [41, 42].

Some researchers have undertaken training courses aimed at improving spatial abilities among university students [31, 37, 39, 45]. In the University of La Laguna, on the other hand, previous research has been done with short improvement courses [4, 38]. The focus of these courses has varied:

- based on classic exercises (views) using pencil and paper;
- multimedia Web-based exercises on-line;
- sketch-based modelling using a calligraphic interface;
- using the Google Sketch-up modelling application as a work tool. (http://www.sketchup.com ).

The objective is for students to achieve a minimum level of spatial ability by the end of their training, which should help them to participate successfully in the regular engineering graphics course taught during the first term in most undergraduate engineering courses.

It is common practice in many Spanish universities to offer a series of remedial courses for freshman engineering students, to enhance their knowledge in basic subjects such as mathematics, physics, chemistry or engineering graphics. These courses are usually taught some weeks prior to the official beginning of the academic term. In other cases, they are concentrated in the first weeks of the term. Attendance is voluntary and these remedial courses are recognised as elective subjects in the personal curriculum of the student.

This pilot study has been designed as a course to improve spatial abilities based on the use of video games on two different platforms: PC type personal computers and Nintendo DS type portable consoles.

*Data questionnaire*

Mindful that the objective was to obtain reliable data on the effect of video games, we designed a new data questionnaire to be filled in by theses students.

Apart from the usual data (age, sex, etc.), the new questionnaire provides details about the participants and the video games. These surveys reveal that the average number of hours of video-gaming for all the students is over five hours a week. All students who play for at least three hours a week are classified as regular players. This questionnaire also asked for information on the platform that students use (personal computer or type of console) and the kind of games used (action, adventure, simulators, skills, intelligence, sport, ability puzzles, etc.).

*Selection and description of the sample.*

At the beginning of the academic year 2007/08 (October), the spatial abilities of engineering students were measured (MRT and DAT) and the questionnaire was completed on a total of 119 first year Mechanical, Electronic and Civil Engineering students at the University of La Laguna (Spain).

Volunteers were called for, from among students enrolled in Engineering Studies at the beginning of the first term, to take part in a spatial ability improvement course based on the use of video games. They were told that the video game that would be used on the course would be 'Tetris'. Initially, 77 students enrolled for the training course, but, for a range of different reasons (lack of time, other commitments, illness, etc.) only 35 students completed the course, so the data that we obtained are based on a sample of this number of students.

The pilot study was conducted during the first week of the academic year 2007/08 so, at the time of taking part in the experience, these students had not attended any Engineering Graphics classes in their degree courses.

Table 1. Test results of participants before intensive course

| | MRT Mean (SD) | DAT Mean (SD) |
|---|---|---|
| Total population ($n = 119$) | 17.55 (8.31) | 39.13 (11.07) |
| Total sample Intensive course ($n = 35$) | 17.43 (8.21) | 41.49 (10.31) |

Table 2. Sample size calculation for the study of improve spatial abilities

| | Estimates standard deviation of the gain scores (S.D) | | | | | |
|---|---|---|---|---|---|---|
| *n* | 4.5 | 5 | 5.5 | 6 | 6.5 | 7 |
| *d* (precision–gain value) 1 | 213 | 262 | 318 | 378 | 444 | 514 |
| 2 | 53 | 66 | 79 | 94 | 111 | 129 |
| 3 | 24 | 29 | 35 | 42 | 49 | 57 |
| 4 | 13 | 16 | 20 | 24 | 28 | 32 |
| 5 | 9 | 10 | 13 | 15 | 18 | 21 |
| 6 | 6 | 7 | 9 | 10 | 12 | 14 |
| 7 | 4 | 5 | 6 | 8 | 9 | 10 |
| 8 | 3 | 4 | 5 | 6 | 7 | 8 |

The spatial abilities of the students who are going to participate in the training course are on a similar level to those of the total population. See Table 1.

Before launching the pilot study we conducted a study of the required sample size ($n$) considering the minimum gain to detect and the standard deviation of the population. The probabilities for Type I error (a-error) and type II error ($\beta$ error) were fixed to 5% and 10%, respectively (normal values). See Table 2.

$$n = (Z_\alpha + Z_\beta)^2 * \frac{S.D.^2}{d},$$

where

$n$ = sample size
Type I error ($\alpha = 0.05$) $Z_\alpha = 1.96$
Type II error ($\beta = 0.10$) $Z_\beta = 1.28$ (power, $1 - \beta$ is the probability of avoiding a type II error)
S.D. = expected standard deviation
$d$ = expected precision.

The 35 students were divided into two sub-groups on the basis of the platform on which they were going to play (21 on PC platform and 14 on Nintendo DS platform), taking 'non-regular players' as a top priority criterion to choose students to do the course on the Nintendo DS platform and the number of available consoles. Interaction on the touch sensitive screen with the pointer was considered intuitive for people who were not familiarised with video games. According to the sample size considered in our study, we should detect at least four points of gain and a standard deviation of gain of between 4.5 and 5.5 points. See Table 2.

Table 3. Test results by kind of player

| | Students | Mean MRT (SD) | Mean DAT-SR (SD) |
|---|---|---|---|
| Total | 119 | 17.55 (8.31) | 39.13 (11.07) |
| Regular video game player | 74 | 19.13 (8.49) | 40.65 (11.09) |
| Non-regular video game player | 45 | 14.96 (7.38) | 36.62 (10.69) |

Table 3 shows the spatial abilities levels of regular video games players and of non-regular players. We conducted the *t-student test* for independent series, with a view to checking whether the means of the two samples were similar or not. In the case of comparing the mean MRT values of players and non-players, this gives a p-value of less than 0.01 ($0.0036 < 0.01$), and for the DAT-SR, a p-value of less than 0.05 ($0.027 < 0.05$). In light of these results, we can fairly say that the mean and standard deviation obtained from the MRT and DAT-SR tests confirm that there are significant differences between the spatial abilities of regular and non-regular players.

Although the object of this paper is not to analyse the results by gender (there are several studies that focus on this aspect [30, 43]), it is interesting to present the results (Table 4), which show several important aspects for future studies:

- The percentage of regular male video game players (75%) is greater than the percentage of female players (30%).
- The effect of being a gamer or not is clearer among women than among men.

These data ratify Saorin's suspicion of 2005: the fact that a regular video games player obtains higher scores in the tests measuring spatial abilities and that female regular gamers are a minority. In general, the initial spatial abilities level of women is lower than that of men.

*Selection of video game and platform*

To select a game and choose a platform for the experience, research has had to be done into the

Table 4. Test Results by kind of player and gender

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | Students | Mean MRT (SD) | Mean DAT (SD) | Students | Mean MRT (SD) | Mean DAT (SD) |
| Total | 86 | 19.74 (8.08) | 40.77 (10.38) | 33 | 11.85 (5.91) | 34.85 (11.80) |
| Regular video game player | 64 | 20.00 (8.47) | 41.55 (9.93) | 10 | 13.60 (6.60) | 34.90 (16.32) |
| Non-regular video game player | 22 | 19.00 (6.95) | 38.50 (11.57) | 23 | 11.09 (5.57) | 34.83 (9.68) |

world of leisure and video games and consoles. The most widely used platforms among video game users are: Personal Computer (PC), Sony PlayStation (model 1, 2 and 3), Sony PlayStation Portable (PSP), Nintendo Wii, Nintendo DS, Nintendo Game Boy Advance and Microsoft Xbox 360. Other platforms less widely used by players include: Nintendo Game Cube, Sega Dreamcast, Nokia N-Gage, Game Park 32 (GP32).

Portable consoles (PSP and Nintendo DS) are well accepted, as users want more and more performance from smaller, more versatile and portable devices. On the other hand, the same video game may be available on different platforms, although it is not played in exactly the same way. Each game is adapted to the controls of each platform. For this study, the categories of video games used are the categories established in the report 'Jóvenes y Videojuegos' drafted by INJUVE, Institute of Youth, which answers to the Ministry of Work and Social Affairs (Spanish government) [44]: Platform, simulators, action, ability, intelligence, practising some kind of sport, sporting strategy, non-sporting strategy, motor, shooting, fighting, graphic adventure, role and arcade games.

The decision was taken to organise this experience into Personal Computers and Nintendo DS consoles. The PC was chosen as the most accessible means for everyone to play and the Nintendo DS console was chosen as the only one that offered the possibility of playing interactively with the screen, using an electronic pencil.

The following conditions were proposed for choosing the game to be used in the training course:

- It must be based on geometric forms or figures.
- It had to be possible to manipulate, rotate, and move the forms, figures, elements.
- It must be related to some spatial ability such as spatial relations or spatial visualisation.
- It must offer the possibility of counting points scored or the levels reached.
- It must be supported on the two platforms: PC and Nintendo DS.
- There must be the possibility of using an electronic pencil on the Nintendo platform.

There are many PC platform based games that meet these requirements [46–48]. Some of these are very interesting: Bloxors [48], Evilcube, Rotation, Laby, Figuras, Gridlock, Faraón [46]. The same cannot be said of the Nintendo DS platform: because it was new on the market, at the time of this work, there were practically no games available that meet all the requirements set. One of the few games available on the two platforms that does meet all the aforesaid requirements is 'Tetris'. For the PC, we opted the free Tetris versions available on Internet. The particular games that were chosen were 'Tetris Arena-Revolution' (available in http://www.terminalstudio.com/tetris.shtml) and '3D-Tetris' (available in http://www.xdgames.com/games/3dblocks). For the Nintendo DS console, 'Tetris DS' was used [49].

*Details of the improvement course*

The course to develop abilities through the use of video games was designed on the premise that it would be done by two groups: one using the PC version of the game and the other group using the Nintendo DS console. The course consisted of playing the different modes of games available both in PC and Nintendo DS versions (Figs 3–9). The course had 5 hours of training and 2 hours dedicated to undergoing tests.

The PC platform course used the following modes of play.

1. *Tetris Classic* (Fig. 3) the basic level consists of shifting and rotating geometric figures simulating bricks (pieces) of different shapes that 'fall due to gravity'. When a complete line is formed (without gaps), the row disappears. Pieces cannot be allowed to build up to reach the top of the screen if the player does not want to lose the game. The Advanced level consists of having to play the game faster. The pieces 'fall' at a greater speed and, therefore, one has to think out the position that we want to rotate, shift and place them quicker.

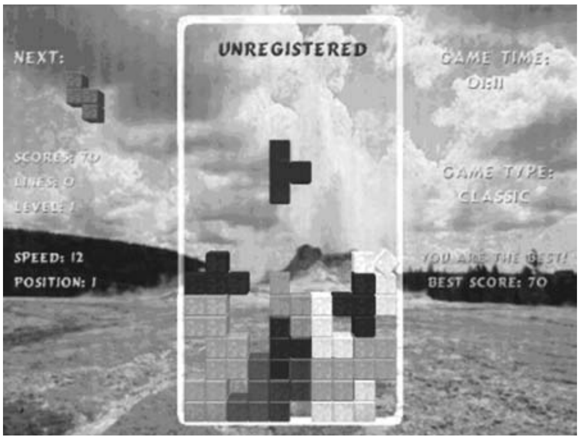


Fig. 3. Tetris Arena. Classic Mode.


Fig. 4. Tetris Revolution. Revolution Mode.

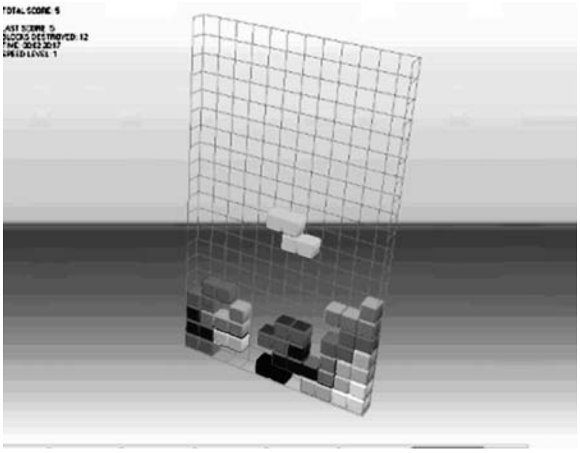

Fig. 5. Tetris Block 3D. Mega Tris Mode.

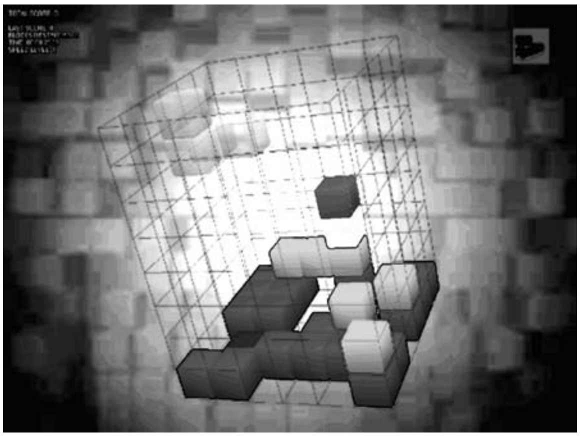

Fig. 6. Tetris Block 3D. Tetrix 3D Mode.


Fig. 7. Tetris Marathon.

2. *Revolution* (Fig. 4) also has basic and advanced levels with the variant that there are pieces with other shapes and pre-created rows of pieces can emerge from the bottom of the screen.

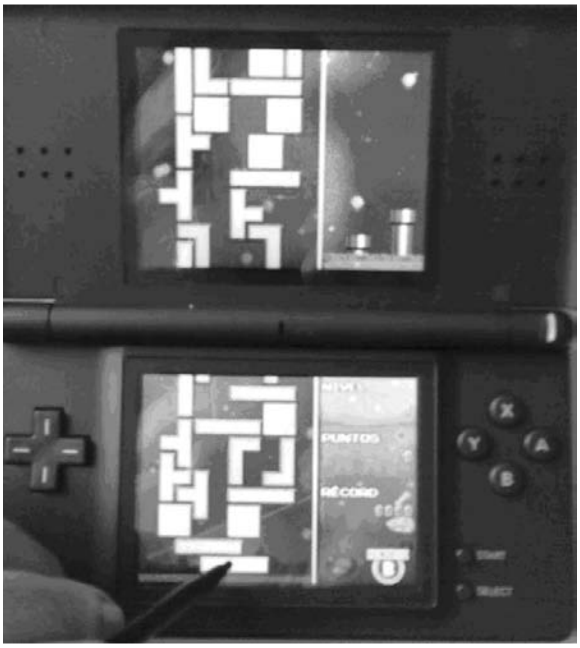


Fig. 8. Tactile—Tower.

Fig. 9. Puzzle—Puzzle.

3. *Tetris block 3D*, this is the same system but, in this case, it is a 3D game.
   a) *Mega Tris* (Fig. 5), the pieces 'fall' to make a wall in isometric perspective.
   b) *Block 3D* (Fig. 6), the area that the pieces fall into is a cube. In this case, an entire surface has to be completed at the same level to make it disappear.

The course on the Nintendo DS platform used the following modes of play:

1. *Tetris Marathon*. This is the same as the *Tetris Classic* mode on the PC platform. Once a number of rows have been eliminated, the player goes to a higher level, on which the pieces 'fall' at a faster rate, so the player has

to think faster about the best way to place the pieces (Fig. 7). The pieces are manipulated with the buttons on the console.

2. *Tactile—Tower*. In this mode of play, the pieces are piled up and the player has to shift and rotate then using an electronic pencil to make full rows, which are then eliminated. The objective is to eliminate all the pieces (Fig. 8).
3. *Puzzle—puzzle*. There are 200 puzzle exercises, in which the player is given a 'wall' with gaps. The player then has to eliminate all the rows of the wall with the three pieces available. The player can rotate these pieces to fit them into the wall with the electronic pencil to make the best fit (Fig. 9).
4. *Tactile—puzzle tactile*. There are 50 puzzle exercises, in which several pieces are piled up and we must use the electronic pencil to eliminate rows, following the instructions that appear at the top of the screen (Fig. 10).

Fig. 10. Tactile—puzzle tactile.

The detailed programme and contents of the course for video game training is specified in Table 5.

## RESULTS

From the mean values of measuring spatial abilities before and after the training course with

Table 5. Contents and timetables of video game training course

| | PC Platform Course. | Nintendo DS Platform Course |
|---|---|---|
| Monday | **9:00–10:00**<br>Data File and Survey<br>Test MRT // Test DAT-SR<br>**10:00–11:00**<br>**Tetris Arena:**<br>Classic Mode (Fig. 3)<br>10:00—10:30<br>Objective: Note highest score.<br>Advanced Mode 10:30–11:00<br>Objective: Note highest score. | **9:00–10:00**<br>Data File and Survey<br>Test MRT // Test DAT-SR<br>**10:00–10:20**<br>**Tetris—Normal—marathon** (Fig. 7)<br>Objective: Note Level, destroyed lines and points.<br>**10:20–11:00**<br>**Tactile-Tower** (Fig. 8)<br>Objective: Note points level 1, level 2, level 3 |
| Tuesday | **9:00–10:00**<br>**Tetris Revolution**:<br>Revolution Mode (Fig. 4)<br>Objective: Note Highest Score obtained.<br>**10:00–11:00**<br>**Block 3D. Mega Tris Mode.** | **9:00–11:00**<br>Objective: Continue with **Tactile- Tower** if did not finish day before.<br>Objective: Note points levels 1, 2, 3.<br>If finished, start **PUZZLE—Puzzle** (Fig. 9).<br>Objective: Note level reached. |
| Wednesday | **9:00–10:00**<br>**Block 3D. Mega Tris Mode**<br>(Fig. 5).<br>**10:00– 11:00**<br>**Block 3D. Tetrix 3D Mode**<br>(Fig. 6) | **9:00–9:30**<br>**PUZZLE—Puzzle** (Fig. 9)<br>Objective: Note highest level reached (max 200).<br>**9:30–11:00**<br>**TACTILE—Puzzle Tactile**. (Fig. 10)<br>Objective: Puzzles 1–50. Note highest level reached.<br>If finished, do **TACTILE -Tower** levels 4 and 5 noting points obtained. |
| Thursday | **9:00– 10:00 Final Tests.**<br>Test MRT // Test DAT-SR | **9:00–10:00 Final Tests.**<br>Test MRT // Test DAT-SR |

Table 6. Results before and after training with video games

| | **MRT Pre-test mean (SD)** | **MRT Post-test mean (SD)** | **Gain MRT mean (SD)** | **DAT Pre-test mean (SD)** | **DAT Post-test mean (SD)** | **Gain DAT mean (SD)** |
|---|---|---|---|---|---|---|
| Total no. student (35) | 17.43 (8.21) | 25.60 (9.26) | 8.17 (4.90) | 41.49 (10.31) | 50.63 (8.53) | 9.14 (4.89) |

Table 7. Results before and after training depending on platform used

| | MRT Pre-test mean (SD) | MRT Post-test mean (SD) | Gain scores MRT mean (SD) | DAT Pre-test mean (SD) | DAT Post-test mean (SD) | Gain scores DAT mean (SD) |
|---|---|---|---|---|---|---|
| Participants with PC | 20.76 | 27.48 | 6.72 | 40.38 | 49.67 | 9.29 |
| $n = 21$ | (8.01) | (9.03) | (4.54) | (11.51) | (8.68) | (5.09) |
| **Standard Error of Mean (SEM)** | **1.75** | **1.97** | **0.99** | **2.51** | **1.89** | **1.11** |
| Participants with Nintendo DS | 12.43 | 22.79 | 10.36 | 43.14 | 52.07 | 8.93 |
| $n = 14$ | (5.73) | (9.19) | (4.76) | (8.30) | (8.40) | (4.76) |
| **Standard Error of Mean (SEM)** | **1.53** | **2.46** | **1.27** | **2.22** | **2.24** | **1.27** |

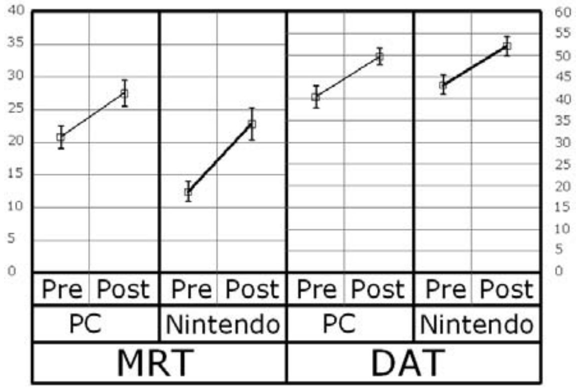


Fig. 11. Mean values and standard error of MRT and DAT scores.

video games (Table 6), we can see that there is an increase in scores after doing the course. We will see if the effect of playing with video games has any effect on improving spatial abilities in this experience. For the statistical analysis, we used a Student $t$-test, taking as the null hypothesis (H0), the fact that mean values for spatial visualisation abilities did not vary after the end of the training course. The $t$-Student for paired series was applied and the p-values obtained are: for the MRT test, it is 1.72E-11 ($t = 9.85$), and 8.46E-13 ($t = 11.05$) for the DAT:SR test, making it less than 1 (*p-value* $< 0.01$) in both cases. Hence we can claim that there is an improvement in results with a 1% significance. The null hypothesis is rejected and we can conclude that the means scores for the experimental group underwent a positive variation, with a significance level of higher than 99%. In other words, the training course using video games had a measurable and positive impact on the spatial ability of students, measured by both MRT and DAT: SR tests.

Analysing the data with respect to platform used (Table 7), we can see that the results improve with the use of both platforms.

Although there are large values for the standard deviation (SD), it is important to note that we are using the standard deviation of the sampling distribution of the mean to compare average data, usually known as standard error of the mean (SEM). Figure 11 presents graphically the data in the MRT and DAT:SR tests.

Table 8 shows that there is a 1% statistical significance between the average scores obtained before and after the course using the two platforms; i.e., that in light of the results, it shows that there is a statistical improvement in the results of the two tests, irrespective of the platform used to play the video games. We can confirm that the probability of spatial abilities improving with the training proposed, is over 99%.

In order to compare the improvement achieved on each platform (PC or DS), we focused on the MRT and DAT gain values in each group. The samples obtained gain values greater than 4 point (expected value in Sample size calculation—Table 2). Applying the *student t-test* for independent series, we compare the mean gain of the two samples (PC vs. Nintendo DS). We obtain for MRT a p-value = 0.029 ($t$ = 2.28) and p-value = 0.836 ($t$ = 0.20) for DAT. In the light of these results, we can see that there is a significant difference in MRT scores and the gain is greater after training with the Nintendo DS device (10.36 vs. 6.72). This difference is not significant however with regard to the gain in DAT scores (8.93 vs. 9.29). Figure 12 shows graphically the values of gain scores.

In this line of research, the PC and Nintendo DS groups, played the same 'Tetris' game but the versions were not exactly the same, so comparisons between the two platforms would make no sense. It would be interesting to find applications that

Table 8. Statistical significance of the results before and after training depending on the platform used

| | MRT | DAT |
|---|---|---|
| Participants with PC | 0.0000014 < 0.01 ($t = 6.77$) | 5.87E-8 < 0.01 ($t = 8.36$) |
| Participants with Nintendo DS | 0.0000018 < 0.01 ($t = 8.13$) | 0.0000091 < 0.01 ($t = 7.01$) |

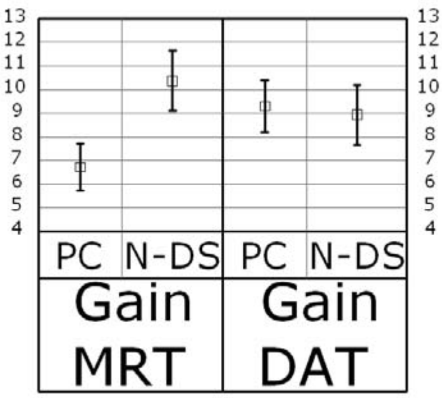


Fig. 12. Gain scores.

allowed players to play exactly the same on the two platforms so differences could be established solely on the basis of said variable.

## CONCLUSIONS AND FUTURE WORK

In our study we can conclude the following.

- In order to improve spatial abilities, we can use students' hobbies as a valid training strategy, without any academic exercises.
- In our pilot study, the use of video games in intensive training courses improves the development of spatial abilities. This result is obtained by only playing video games (Tetris), without any need to provide theoretical contents about the subjects of Engineering Graphics.
- The two platforms used for training, PC and Nintendo DS, improve spatial abilities.
- Playing 'Tetris' on Nintendo DS develops the ability to imagine rotations of objects in 2D and 3D (spatial relations) to a greater extent than playing Tetris on a PC.

In many university systems, like the Spanish one, there is a growing diversity in the curricula that students have followed before entering the university undergraduate level. This means, in the case of subjects related to the Engineering Graphics field, that many students have a poor background on this topic, and also underdeveloped cognitive skills for manipulating graphic information in their mind.

The study presented in this paper shows that a certain kind of videogame (those that are centred on specific geometric manipulations) can help to improve the spatial abilities that are required for many engineering problem solving activities.

In a context where engineering educators must be continually looking for strategies to implement the most effective instructional approaches, video game technology can provide educators a wealth of potential tools.

The employment of specific video games as a complementary activity to classical academic tasks can promote student motivation and a positive attitude as we have noted during the development of this study.

We think that there are two basic approaches to integrate video games as a complementary activity in the specific context of spatial abilities development. One is based on analysing available commercial titles, as in the study presented here. The other approach would be to develop ad hoc videogame-like applications that could combine the look and feel of videogames and perhaps some contents related to the Engineering Graphics field. Our research group is developing research activities following both approaches and, in both cases, the use of mobile platforms (in this study the Nintendo DS console) has shown very attractive for students.

There are many open issues that will require further research activity; for example, it would be interesting to conduct a specific analysis to determine what the importance is of the user interface on the abilities development.

Tactile, mouse and electronic sketching would be the first candidates to be evaluated, as there are commercial devices that use it. We also want to clarify the relation of gender and video games in order to improve the spatial abilities training.

Finally, in the future we also want to investigate other non-conventional strategies of improving spatial abilities that use technology in an easy-to-learn way. We are designing a training course using Augmented Reality. This technology allows students to manipulate virtual 3D objects with their own hands. We also want to make surveys about the attitude and motivation of students towards these learning methodologies and technologies.

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