This paper shows the results derived from the research focused on evaluating the spatial abilities presented by the students of a center of the Community of Madrid, Spain. For this, a test of twelve questions was carried out, with an approximate duration of 10 minutes, in which three blocks of questions were distinguished, each of them related to a different spatial ability: relation of three-dimensional figures with their development in 2D, spatial rotation of three-dimensional figures and section produced by a plane in 3D figures. In a first analysis of the results, differences are observed in the ability of the students to solve the different types of problems, with the section-by-plane exercises in which the worst results were obtained. On the other hand, when focusing attention on the sex variable, differences are observed in the results, since, especially in the case of spatial rotation, men obtained better scores than women. In this way, with this case study, a possible research route is opened, since if the sample is enlarged and representative results are obtained, one could know firsthand the real difficulties presented by the high-school students in spatial skills; which would ultimately help rethink the subjects of the graphic subjects with the idea of improving the development of these skills.

Keywords: spatial skills, technical drawing, high-school, gender.

1 INTRODUCTION

There are many studies that demonstrate the influence of different factors on the spatial abilities of students, understanding as such skills the ability to generate, preserve and manipulate abstract visual images [1-3]. These factors can be, among others: gender, the social context in which the student grows, leisure activities carried out during childhood, training at school, etc. [2-5]. Of all of them, gender is one of the most studied, and among the most relevant results of these investigations, it has been observed that women are less likely to obtain high scores in tests such as the Mental Cutting Test, while men show a greater dexterity in most spatial skills. However, these observations are not conclusive, since there is no consensus in the scientific community since contrary results are also obtained in other studies [6-7].

The subject of Technical Drawing is included in the specialty subjects that make up the current Technological High-school. However, the previous training received for this subject in terms of the development of spatial capabilities is quite limited, since only exercises -in specific didactic units- are included in the subjects of Plastic, Visual and Artistic Education and Mathematics. This lack of training results in students having to make a greater effort to take the subject of Technical Drawing in High-school, since they encounter obstacles in the representation of perspectives in isometric or the realization of sections in Dihedral. Faced with such problems, there is a higher rate of abandonment and lack of motivation [8]. In the literature related to this problem, has been investigated about the best techniques or tools for the development and training of spatial skills, with many possibilities or paths to choose by the teachers. Among them is the manipulation of objects and games related to construction from an early age, the realization of freehand drawings, different training tests or virtual platforms with different exercises. However, due to the great variety of techniques and the difficulty of evaluating them comparatively, there is no agreement on which is the most effective or recommendable [9].
2 METHODOLOGY

The methodology of this work has been broken down into several sections, focusing in the first instance on the contents of the Technical Drawing subject in high-school and the spatial skills that are related to them. Subsequently, a test has been designed that includes the three most studied spatial abilities in the literature: relation of three-dimensional figures with their development in 2D, spatial rotation of three-dimensional figures and section produced by a plane in 3D figures. Finally, an analysis was made of the context of the center and the population sample that was available for this work.

2.1 Curricular analysis of the subject

The Technical Drawing is a means of expression and communication essential both at the level of scientific research and in the graphic understanding of technological projects for the purpose of creation, design, and manufacture [10]. It is a discipline that allows the student to have a capacity that allows him to develop reasoned solutions to geometric problems in the plane and space. Once the students know the language of graphic communication, this configures their cognitive processes and the way in which they approach solving problems with greater clarity, acquiring a greater capacity for abstract thinking and formulating ideas. Table 1 shows the different blocks of contents included in the subject of High School Technical Drawing and the spatial skills involved in them.

<table>
<thead>
<tr>
<th>Trimester</th>
<th>Contents</th>
<th>Spatial Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>Geometry and Technical Drawing develop knowledge of Euclidean space through flat geometry, construction of figures and transformation operations in the plane.</td>
<td>Spatial rotation of figures. Relationship of 3D figures with their 2D development.</td>
</tr>
<tr>
<td>Block 2</td>
<td>Representation Systems aims to give a two-dimensional graphic description of environments or three-dimensional objects using descriptive geometry techniques.</td>
<td>Relationship of 3D figures with their 2D development. Section by a plane in 3D figures.</td>
</tr>
<tr>
<td>Block 3</td>
<td>Standardization. In this way, conventions and standards complete and generate a more tangible vision of the need and applicability of Technical Drawing in the real world.</td>
<td>None.</td>
</tr>
</tbody>
</table>

On the other hand, computer-aided design software, which allows applying knowledge to engineering, architecture, and construction, it is necessary to include them as one more tool to help develop the content of the subject, serving, in turn, to motivate the students and equip them with a more complete vision of the subject. These computer tools for their ease of use and multiple viewing possibilities help in turn to exercise spatial ability and simplify some of the most complex problems of the subject, thus limiting the possible differential gap between men and women in this discipline.

2.2 Test design

Preparing a good questionnaire is a complex task and requires extensive experience since asking is quite simple, but finding the right questions or those that interest us for the study is complex and difficult. For the realization of this work it has not been tried to reach a comparable sample to the whole population, but to know the reality that nowadays is given in the educative centers and to lay the bases for later studies.

The age of the students between 16 and 18 years of age has been taken into account, the difficulty of carrying out the fieldwork within the educational center and the selection and order of the questions to obtain relevant results. In this way, the questionnaire was divided into three well-differentiated parts corresponding to the three spatial abilities that were wanted to study. The questions presented a high-school level and the time to answer it was 12 minutes.
2.3 Context of the center under study

The center under study is a cooperative of teachers and administration and services personnel founded in 1975 in the neighbourhood of Vallecas in Madrid. The school covers a wide variety of students and different economic and cultural levels, with three lines in high school and five high school groups (social sciences, pure sciences, health sciences, and humanities).

The sample collected in the Space Skills Measurement Test consisted of 59 students, of whom 59.3% were men and 40.7% women. Regarding the distribution by course, the majority (74.6%) belonged to the classes of 1st High-school year, compared to 25.4% who studied in a higher course. As a last feature of the sample to be reviewed, 59.3% took or took the course of Technical Drawing at the time of application of the test, compared to 40.7% who did not.

3 RESULTS

As noted, the test consisted of three blocks: spatial relationships, mental rotations, and sections produced by cutting a plane. The average scores of the students can be seen in Table 2. As indicated by the data, the exercises of mental rotations were the best executed by the students (2.3 points out of 4), compared to the exercises of sections produced by the student. Cut of a plane (1.2 points on 4). These differences may have been caused by the level of difficulty observed in the exercises, although it is true that tasks such as spatial rotation are those that traditionally lead to greater differences between men and women, in general terms, the fact that the students of first of high-school have not studied technical drawing in previous courses, can be a determining factor when performing exercises of sections in figures.

Figure 1. Examples of questions of Test (a) Relationship of 3D figures with their 2D development. (b) Spatial rotation and (c) Section by a plane in 3D figures
Table 2. Average scores of the students according to the type of exercise

<table>
<thead>
<tr>
<th></th>
<th>Spatial relations (0-4)</th>
<th>Spatial rotation (0-4)</th>
<th>Section by plane (0-4)</th>
<th>Total (0-12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average scores</td>
<td>2.34</td>
<td>2.61</td>
<td>1.22</td>
<td>6.17</td>
</tr>
</tbody>
</table>

In Figure 2 you can visually check the percentage of errors and successes of each exercise. As the medias indicated, the percentages of errors in the section exercises stand out.

The main objective of the present study was to analyze the results by focusing on the sex variable. Figure 3 shows the results disaggregated by sex. Where the greatest differences are observed between men and women in the space rotation exercises, there is a difference in the percentage of correct answers of more than 30 percentage points, in favor of men.

It is also interesting to know the percentage of correct answers per question according to whether or not the students take technical drawing (Figure 4), since from these results it is derived that the learning of this subject mostly helps to develop the spatial abilities of the students and to equip them with of greater resolution capacity in this type of tests. This makes that in this type of tests increasingly...
common in companies and selection processes, candidates with a science profile have a slight advantage in certain psychotechnical questionnaires.

Finally, also, it was possible to obtain the ratio of successes between the first and second-year students of high-school who were taking technical drawing (Figure 5). From which it is deduced that the level of maturity of the students of superior courses and their greater knowledge, helped them to obtain better results in the test carried out.

3.1 Discussion of the results

An important part of the work was the interpretation of the results, for this, statistical tests were performed that allowed to obtain conclusions about the scores obtained in the test.

As can be seen, at first glance there are variations in the success percentages of each block according to the sex involved in the completion of the questionnaire. In addition, it has been found that the difference of means in the total scores is not statistically significant, but does the same thing happen when analyzing the scores block by block? With this objective, a nonparametric statistical test of means contrast (Mann-Whitney U) with a significant level of 0.05 was performed and the results are shown in Table 3.
Then, as can be seen, there are no significant differences in the average scores of men and women in Spatial Relations or in Spatial Rotation, if instead in the Section Test for a Plane with a level of significance of 0.039. It should be noted that these results only correspond to the sample analyzed and that they should be contrasted through more tests and expanding the existing sample.

4 CONCLUSIONS

The spatial skills are a skill that should be trained from the primary school in all educational centers, from their development skills such as the abstraction and visualization of objects are exercised. It is, therefore, a tool that should be understood as elementary not only within the student body of sciences, since more and more in business schools and private companies are carried out psycho-technical tests in which these skills are involved.

This work tries to shed some light on the possible differences between men and women in terms of spatial capacity. It is true that the educational model has traditionally been conceived by and for men, and therefore it has always been those who have played a fundamental role in areas such as engineering or architecture. The understanding of the human brain and the search for difficulties in learning that can be found in both genders helps to improve the quality of education and generate new methodologies that allow acquiring the competencies that the current legislation marks.

Despite analyzing a small sample, there have been some differences between men and women in the realization of tests such as Section by a 3D plane. This work suggests extending this research in search of more evidence and the realization of other alternative tests that allow knowing better the origin of these differences and obtain results extrapolated to a wider population than the one presented here.

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