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Specific Professional Skills Development for Engineering Studies: Spatial Orientation*

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The spatial skills are an active field of research, especially in the engineering area. Several authors connect high levels of spatial kills with the success in technical careers. One of the components of spatial skills is spatial orientation. Many studies show that providing the appropriate material may develop spatial skills. However, a plan aiming for the development of spatial orientation skills in formal teaching is still missing. This paper presents an innovation in the teaching strategies through a Geographic Information Technologies workshop which aim is development of the spatial orientation. The workshop's study was completed during four academic courses with 248 university engineering students involved. A control group was created with 35 students using conventional teaching methods for determining if the increase in the spatial orientation skill is due to the effect of this workshop. The result shows significant statistical gains over the spatial orientation skill of 19.21 degrees. The results from the control group confirm that students who have not undertaken specific training didn't develop their spatial orientation skill.

Keywords: geographic information technologies; infrastructure for spatial information in Europe; spatial orientation; spatial skill

1. Introduction

The spatial skills are currently a competence that should be acquired in a large number of engineering degrees adapted to the European Space for Higher Education, which educational model is based not only on knowledge's acquisition, but also on development of the students' skills [1]. Over the last half century, the spatial skills enjoyed increased recognition although they didn't receive the same attention paid to other skills connected to verbal and numerical abilities [2].

Several authors connect a high level of spatial kills with success in technical careers: spatial thinking is essential for scientific thought and it's used for the representation and handling of information during learning as well as for resolving certain problems [3–5]. The spatial skills became an active field of research in the engineering field indeed. The development of spatial skill abilities by engineering students is connected to their future chances of success in their professional careers [3, 4, 6, 7].

Some people may have a higher degree of innate spatial skill than others, which also happens in other skills such as writing, mathematics, etc. However, most people can eventually acquire the spatial skill through patience and practice [8]. Many studies show that providing the appropriate material may develop spatial skills [9–11, 21] and there is common agreement that spatial skill can be improved through training [8].

There are several classifications available about the study of the components belonging to spatial skills [13, 14]. Some authors adopt a simplified ranking based on two components: spatial relations and spatial visualization [4, 5, 15, 16, 17].

Other authors consider that spatial orientation is one of the main components of the spatial skills besides spatial relations and spatial visualization, [1, 18–20]. The spatial orientation skill is defined as the ability to self-orientate relative to the environment; and the awareness of self-location [21]. Other authors define it as the ability to orientate physically or mentally in space [22].

The cartography, maps and street plan are an activity field where spatial orientation abilities are widely used [23–27]. When we check a map or plan we need to determine the orientation of elements relative to known links (besides scale's perception and symbols' interpretation) in order to orientate them in space [28]. The interpretation and communication of figured information (maps and cartography) are abilities connected to spatial orientation [4]. The spatial learning includes all knowledge acquired by studying maps and charts [29].

Proper space conceptualization is needed for engineering and other science or mathematics dis-

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ciplines [10]. Besides, the engineer needs to interpret and develop pieces of machinery displayed in both front and section views. The engineer also needs to locate those pieces in a real 3D environment through the spatial orientation. Hershkowitz, Parzsyc and Van Dormolen (1996) state that Euclidean geometry starts with orientation in real space: 'the experience in space includes the position of objects relative to an observer'. These authors state that a well planed spatial education is needed for the acquisition of spatial reasoning and thinking. Having this in mind, they suggest activities connected to the interpretation of maps and plans [30].

The spatial orientation is a field of great interest among teaching institutions. It's also included as a subject that must be taught across curriculum directives of the minimum teaching decree issued by the Ministry of Education and Science for primary and secondary education [31, 32]. Several institutions such as the National Council of mathematics teacher [33] state that development of spatial orientation is one of the sources for physical world's description and modelling. Certain fields such as didactic mathematics perform research studies about teaching and learning processes of spatial orientation [34–36].

Several competences connected to the analysis and obtaining of geographic or cartographic information as well as its sketching and treatment, appear in the university context and among new engineering degrees adapted to the European Space for Higher Education as stated on CIN orders from the Ministry of Science and innovation on the official state bulletin [37–39]. On the professional field, the appearance of Geographic Information Technologies (GIT) eases the use of mapping and land or space information over virtual environments becoming a tool for the practice of the engineering career. This skill should be acquired by undertaking subjects such as Topography, Graphic Expression, Remote Sensing, Design, Geometrics etc., but no specific actions are planned for its development on formal teaching. We should also underline the research about methodologies, platforms and tools as they allow the development of innovative teaching strategies. They also allow the acquisition of competences connected to the spatial orientation skills of engineering students at the university.

Having this in mind, this paper presents a teaching methodology which aims at development of spatial orientation skills.

2. Teaching-learning methodology

The teaching-learning methodology consists in performing the SDI-Workshop through Geographic Information Technologies which are defined as those disciplines that allow generating, processing and sketching geographic information or variable subject of being geo-referred in space through the Cartesian coordinates system [40–44]. GITs are a new emerging field belonging to the geographic information with online availability. They stand as one of the three biggest growth industries in the United States, together with nanotechnology and biotechnology [45, 46]. In fact, the higher number of education centres teaching subjects related to GITs through several learning levels are all located in the United States [41].

The GIT used in the SDI-workshop is the Spatial Data Infrastructure. A SDI, also known as Geoportal, consists in a set of resources (catalogues, servers, software, data, applications, web pages, etc.) dedicated to management of geographic information (maps, orthophotos, satellite images, location names, thematic information, etc.) that are available online. The Infrastructure for Spatial Information in Europe (INSPIRE) is an initiative from the European Commission. It establishes the Infrastructure for Spatial Information in the European Community, regulating all standards, technical protocols, organisational and coordination aspects as well as informative policies regarding data access or creation and maintenance of spatial information. The INSPIRE Geoportal offers to all users the chance of enjoying free online access to all geographic data and geographic information databases, metadata, sets and spatial data services from several European state members' organisations [47].

Each student performs a specific test before and after taking part in the SDI-Workshop. That specific test measures the spatial orientation skill for checking out if there is an improvement after taking part in the workshop. The test undertaken is the Perspective Taking Spatial Orientation Test.

A control group was created with 35 students for determining if the increase over the spatial orientation skill is due to the effect of the activity or if it's due to the memory effect from the test. This control group is subject to Perspective Taking/Spatial Orientation Test twice without taking part in the workshop. This control group learned the subjects included in the workshop through conventional activities (master classes) without any SDI use.

2.1 Participants

The sample of this study is composed of 283 students from three engineering degrees belonging to La Laguna University. In this sample there were 248 students who took part in the SDI-Workshop meanwhile 35 of them composed the control group. The study was conducted during four academic years 2009–2010, 2010–2011, 2011–2012 and

Table 1. First Year Seminar activities' summary.

Phase	Description	Time
1. Introduction	Introduction	3 ch
	Training	2 hwh
2. Improvement	Practical Exercises (5 units)	$3\frac{1}{2}$ ch

ch: classroom hours. hwh: homework hours.

2012–2013. In 2010 a similar experience took place with 46 engineering students from the same degree [48].

2.2 SDI-Workshop structure

The SDI-Workshop is divided in two phases (Table 1).

1st phase: Introduction

Introductory session (3 hours): Description of the SDI Geoportal and its applications. The students learn operating commands and contents while getting used to the interface through the measurement of areas and distances while obtaining profiles and visualizing the ground through different methods in two and three dimensions. For completing these activities they should also check the database indeed.

Training session (2 hours): It's designed having in mind all practices which should be carried out at home by the student himself with tools that had been used at the classroom. The geographic evolution analysis is proposed to the participants by focusing on a certain zone previously chosen by the student. Besides, they are provided with a 10 pages document that includes cartography and imagery for exercising their spatial orientation abilities.

2nd Phase: Improvement

Practical exercise ($3\frac{1}{2}$ hours): The proposed exercise contains five blocks of questions for the students where each one is designed for executing all commands while checking out the Canary Islands SDI Geoportal.

Unit I: Measurement. Several questions are asked about operating commands for measurements of distances, areas and slopes.

Unit II: Orientation. Two exercises are proposed and students should use their spatial orientation skill for solving them. On the first exercise they should point out the sun's position at the exact hour when picture was taken using ortophotos on display. Meanwhile, on the second exercise the routes should be covered across a certain area using a small scale denominator on display. During this route, the student should recognize known places using the cartographic format during the outward journey and ortophotos upon their return. When the route covered is the same, the Geographic North position should be activated and deactivated.

Unit III: Query. Consists of questions' set where the students may access contents from the geo-referenced database. They are also asked about certain variables and data listed in the Canary Islands SDI database.

Unit IV: Positional Scenario. In this section, it is required to choose between several 2D and 3D formats around a specific location.

Unit V: Dynamic Scenario. As in previous case, the student is required to choose between different 2D and 3D display formats across a certain route that should be covered.

The hardware used for undertaking the workshop consists of personal computers with online access.

2.3 Spatial orientation skill measurement

The spatial orientation may be quantified through instrument's measures (test) [49]. For taking these measurements, the Perspective Taking/Spatial Orientation Test developed by Hegarty, Kozhevnikov and Waller from the University of California, Santa Barbara was used. This test has already been used in previous experiments [50, 51], by the Department of Psychology, University of California, Santa Barbara, USA and Miami University, Oxford, OH, USA. This version of the test was also used by Hegarty and Waller (2004) [51], while a revised version of the test was also used by Kozhevnikov and Hegarty (2001) [50].

This test consists of 12 exercises, where the students should choose a direction between six different options. Table 2 shows the overall scores as well as the average gains acquired. The score for each item is the absolute deviation in degrees between the participant's answer and the correct direction to target (absolute directional error). A participant's total score was the average deviation across all items. If a participant did not point to any target, a 90° score was assigned for that item [51].

It should be underlined that the Perspective Taking/Spatial Orientation Test overall score is the deviation between the participant's answer and the correct one; so the lower the score obtained, the greater success rate.

2.4 Hypothesis

The hypothesis of origin is that:

A SDI-workshop is a valid tool for the improvement of the spatial orientation skill.

For validating the work hypothesis, a null hypothesis (H0) will be set so the assumption will be

Table 2. Results from the Perspective Taking Spatial Orientation Test in the SDI-Workshop sorted by academic courses

	Perspective Taking/Spatial Orientation Test			
Degree	**N**	**Pre-test (s.d.)**	**Post-test (s.d.)**	**Gain (s.d.)**
Agricultural Engineer	80	49.33 (28.11)	33.05 (24.05)	16.29 (14.56)
Civil Engineer	122	46.35 (24.26)	24.33 (15.25)	22.02 (16.59)
Marine Engineer	46	44.30 (22.84)	27.49 (15.53)	16.82 (13.06)
Total	248	46.93 (25.29)	27.72 (18.91)	19.21 (15.54)
Control Group	35	46.98 (21.67)	41.70 (27.04)	5.29 (19.21)

s.d. Standard deviation.

validated or not through statistical inference methods.

3. Main results. Actual benefits of the approach followed for promoting professional skills

Table 2 shows the mean scores and the typical deviations obtained by participants in this study according to their degree. The range of the average gain appreciated varies between a 16.29 minimum and a maximum of 22.02 sixtieth degrees.

A t-student was performed over paired samples from the control group, showing no significant differences between pre-test and post-test scores (p-value = 0.113).

After applying the Levene test for checking the variance homogeneity (p-value = 0.102), an Anova was performed for stating any significant difference between the observed gain across the different groups, obtaining the following differences: $F_{3,279} = 251.92$, p-value < 0.001). Post hoc Tukey comparisons show significant difference with respect to control group, but don't exist differences between the groups which took part in the workshop belonging to different degrees. The average gain from these groups is 19.21 degrees (sd = 15.54), p-value < 0.001.

The multiple regression model obtained in this analysis is shown in Equation 1. That mean gain obtained by the experimental group, in comparison with the control group, depends on the value of the Pre-Test (interaction, $F_{1,279} = 7.712$, p-value = 0.006). A positive correlation was observed between Pre and Post-Test Score (r = 0.747, p < 0.001) (Fig. 1). Participants with good initial results also obtained good scores in the post-Test. Participants

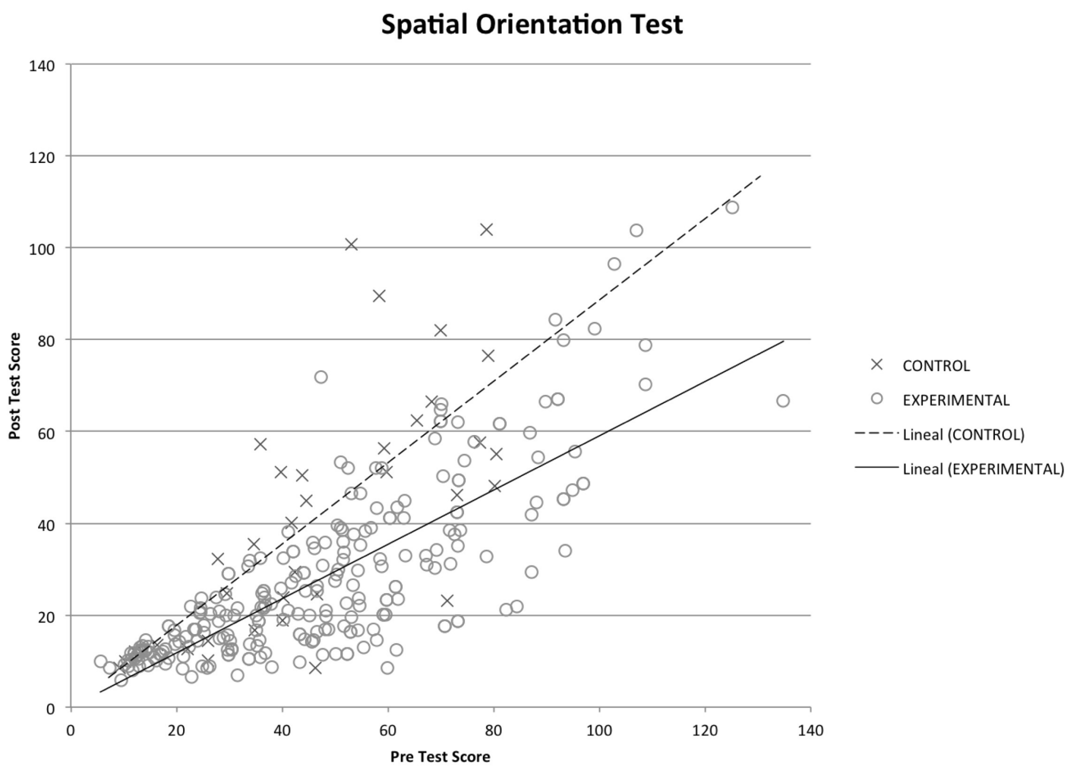

Fig. 1. Correlation between Pre and Post-Test Score.

with lower scores in the test obtained the most important gains.

$$postTest = 0.091 - (group = Experimental)* (0.099 + 0.295 * preTest) + 0.0886 * preTest$$

Equation 1. Multiple regression models

4. Future issues

As a future work belonging to the environment of this research, the usefulness of digital tablets as support for geospatial information could also be analyzed as well as planning the spatial orientation performance in open environments taking advantage of the 3G network.

5. Conclusions

Once the SDI-workshop is over, we may conclude that the spatial orientation skill may be improved through specific training. In the experience carried out by 248 students from three engineering degrees during four academic courses, the results show a significant difference over the spatial orientation skill which varies between a 16.29 minimum rank and a 22.02 maximum degrees rank. There are no gain differences between the spatial orientation values belonging to different degrees.

Considering the 2010–2013 period, we may confirm that there is obvious effect from the SDI-workshop over the average spatial orientation scores. That effect increases the spatial orientation of those subjects who undertook training, showing an average gain of 19.29 degrees. The results from the control group confirm that students who have not been subject to any specific training didn't develop their spatial orientation skill.

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