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Assessing spatial competence in secondary education students in the Balearic Islands (Spain)

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Abstract

The growing interest in geography over the last decades, thanks to the introduction of GIT, contrasts with the poor level of geographic literacy of the population that academic literature reports. The purpose of this study is to analyze the spatial skills of secondary education students in the Balearic Islands by examining two parameters: place location knowledge (PLK) and area estimate of different regions of the world. This was accomplished through the design of an online instrument on which the location and area estimate of 9 territorial units of the world had to be provided, to subsequently conduct a test that was completed by 275 students in their third year of compulsory secondary education at 8 school centers. The final results show poor knowledge of the abilities that students were assessed for, which is consistent with the findings of other similar studies. The students could only clearly identify the territorial units that were nearest, those within the Mediterranean regional area, and the largest. This research is a step forward in the diagnosis of geography teaching as a basis for designing future teaching strategies to improve geographic knowledge and strengthen spatial competence.

Keywords: Geographic Literacy, Spatial Competence, PLK, Area Estimate, Secondary Education

1. Introduction

Over recent decades, interest in geography has grown (Murphy, 2018), especially since the introduction of Geographic Information Technology (GIT). The ability to critically and intelligently use geotechnologies has become a bonus for effective participation in society (Bednarz et al., 2006), and geographic knowledge is highly appreciated as a means to understand the world (van der Schee, 2012). Even so, many studies refer to the problematic situation of geography in education (van der Schee, 2014), while others reveal the population's low level of geographic literacy (Raento and Hottola, 2005). This trend is noticeable both in countries where geography has been given a leading role in the education system (Innes, 2012) and in others, such as Spain, where the subject matter has played a less significant part (De Miguel, 2018). However, despite the remedial care given to geography in education by different assessments, specialized analysts claim that there is a pressing need for developing research in geography education (van der Schee, 2014).

Geographic literacy, spatial intelligence, spatial thinking, spatial and geographic abilities, and spatial competence are concepts that have been commonly used to establish the theoretical framework that encompasses studies on didactics in geography.

Geographic literacy is the training acquired to recognize geographic space, as well as the ability to understand, process and use basic geography skills. It includes place location knowledge, map-reading skills, and the understanding of human and social systems in connection with the natural environment (Zhu et al., 2016). Certain studies reveal that students whose geographic literacy level is low have greater difficulty in using maps (Utami et al., 2018).

Spatial intelligence is defined as the necessary cognitive matrix of abilities to move around or represent space (Gardner, 1983). It materializes in a series of competences, among which the most important are orientation and representation, with an interrelation, on the other hand, between the development of "practical" space and "represented" space (cognitive). Indeed, understanding this interrelationship is relevant in the area of education, since geographic knowledge, among others, can clearly contribute to the development of said spatial intelligence (Sarno, 2012).

Geographers and scholars from other disciplines have devoted special attention to the concept of spatial thinking. Spatial thinking and geographic thinking are, actually, not synonyms but complementary concepts. The former is more concerned with cognitive processes related to spatial intelligence whereas the latter is more strongly linked to the subject of geography itself (De Miguel, 2015). Nevertheless, geographers remain interested in spatial thinking because they are convinced of its importance in students' ability to learn the subject (Bednarz and Lee, 2019) and how the discipline contributes to their development (Yaniet al., 2018). However, there is no consensus as to its definition, since different terms are used interchangeably: spatial ability, spatial cognition, or spatial thinking (Ishikawa, 2013). Bednarz and Lee (2011) argue that spatial thinking, which is essential to science and engineering, comprises three components: the nature of space, the methods used to represent spatial information, and the process of spatial reasoning. Spatial ability is associated with thought and has a more limited scope. It encompasses two dimensions: spatial visualization and spatial orientation. Nevertheless, geographers have proposed a third dimension: understanding spatial relationships. Other authors associate the concept with visual intelligence, which is a characteristic that fosters spatial reasoning through the use of graphs, maps, tables, illustrations and other types of visual material. Visual intelligence allows students to come up with ideas and solutions to problems in their minds before trying to verbalize or implement them (Mulyadi et al., 2018). Gómez-Trigueros (2020) uses the term spatial competence to define the ability to represent, generate, remember and transform non-linguistic, symbolic information, such as the ability to read, understand and use a map for spatial orientation purposes.

Many authors advocate a greater use of GIT in teaching to improve students' spatial skills. There is proof of the effectiveness of geospatial technology, not only for geography learning but, especially, for the development and training of students' spatial thinking (De Miguel, 2015; Gómez-Trigueros, 2020; Martinha, 2020). Moreover, using maps as part of the learning process promotes the acquisition of spatial skills such as recalling routes and landmarks, as well as analyzing and predicting the impact of interrelations between phenomena (Hilman and Mainaki, 2013). Harwood and Rawlings (2001) examined the mental maps drawn by 26 English students and found significant improvement after 6 classes using a practical atlas.

Different tools have been used to assess spatial competence, spatial skills, spatial thinking and spatial intelligence. Some studies propose tests or question-based tools (Ishikawa, 2013; Somantri, 2022; Mulyadi et al., 2018), whereas others engage in cognitive research using mental maps or cartographic sketches as tools to analyze geographic knowledge

(Harwood and Rawlings, 2001; Binimelis et al., 2023). These tests assess a variety of parameters: orientation and direction, spatial patterns, map overlays, spatial correlations, location, the establishment of hierarchies, size comparison, etc. (Harwood and Rawlings, 2001).

Although there are discrepancies regarding the meaning of geographic literacy, many believe that place location knowledge (PLK), or the capacity to locate and name places (such as countries, cities, or geographic features) on a map, is one of its main components and can partially reflect different levels of literacy (Zhu et al., 2016). PLK is useful for many common practices such as understanding weather reports and international news, deciding where to live, or enjoying travel experiences (Torrens, 2001). Over the last 30 years, many studies have addressed the topic, revealing a poor level of knowledge in the surveyed population. Torrens (2001) examined PLK in a sample of more than 400 secondary education students in Dublin to assess the features of the places under analysis that give them greater or lesser visibility, as well as the personal characteristics of the respondents that account for their PLK. In his study, students were asked to locate elements in Ireland, Europe and the world on a blank map. Dal (2008) assessed knowledge of the location of climates in secondary and university-level students in Turkey. Reynolds and Vinterek (2016) used mental maps to examine the knowledge of countries across the world in students from Sweden and Australia. Their work proved that, while students were influenced by their national space, the media and popular culture also had an impact on their world views, which are very similar. In like manner, Waddington and Shimura (2019) assessed the knowledge of secondary education students in Japan and Ireland regarding the location of countries in the world.

Another analyzed parameter in geographic literacy research is area estimate and size comparison of different regions. In their study, Battersby and Montello (2009) were particularly interested in whether exposure to map projections, especially the Mercator projection, had played a significant role in the introduction of area distortions in the global-scale cognitive maps of university-age respondents. The participants in their research were asked to estimate the area of 26 regions located around the world, comparing them with the area of the United States, which was assigned a standard value of 1000 units. In another study, Lapon et al. (2019) developed an application that allowed participants in Belgium and the USA to compare the area of several countries and continents with that of Europe and the USA.

Geographic literacy in Spain has been scarcely addressed and the population’s body of geographic knowledge is poor. The legislative framework for education is ever-changing, specialized teaching staff is scarce and, besides, a lack of cognitive and procedural contents linked to geographic knowledge has been identified. These are some of the continuing problems of the education system (Marco Amorós, 2002; Binimelis et al., 2023; Gómez-Gonçalves et al. 2021) that help to understand where geography currently stands. The geographic knowledge delivered in secondary education has been traditionally based on rote learning (De Miguel, 2013) and the existing curriculum does not include any specific competences or assessment criteria that suggest directly working with GITs, despite their relevance to geographic knowledge and the development of spatial abilities (Pons, 2022).

Against such background, the main purpose of this study is to assess the level of spatial competence of compulsory secondary education students in the Balearic Islands. This will be achieved by examining two parameters: PLK and the estimation of the area of different regions across the world. Several questions are posed: will the poor baggage observed in the tests carried out with university and school students around the world be repeated in Balearic students?; what are the geographic features (distance, area, latitude) of the places analyzed that can influence students’ capacity to answer correctly?; is there a relationship between the ability to locate regions and that of estimating areas?; can sociodemographic variables such as gender or travel experience influence students’ level of geographic literacy?

2. Methodology

This research is part of a broader project whose purpose is to work on the Diagnosis-Intervention-Assessment triad (Harwood and Rawlings, 2001). The diagnostic phase is aimed at detecting geographic literacy among third-year compulsory education students from 8 different secondary schools in the Balearic Islands, 4 pilot centers linked to the members of the project's work team and 4 control centers. Subsequently, within the subject of geography, a didactic intervention exercise will be performed with the students in the pilot centers, aimed at improving their spatial abilities as well as their geographic knowledge. Finally, progress in knowledge acquisition and spatial competence will be evaluated by applying an assessment test to both pilot and control centers.

The current study analyzes one part of the results obtained in the first diagnostic phase (Figure 1). The development of the test required the preparation of an online map editor instrument to identify the level of geographic knowledge as well as the spatial skills of the participating students. The proposed structure was similar to that of other previous studies (Raento and Hottola, 2005). There was a total of 86 questions arranged into 5 sections: students' sociodemographic data; spatial competence; local dimension measurement; global dimension measurement; and location of the elements on a digital map. The instrument was finally validated by experts and using a pilot test in Spring 2023.

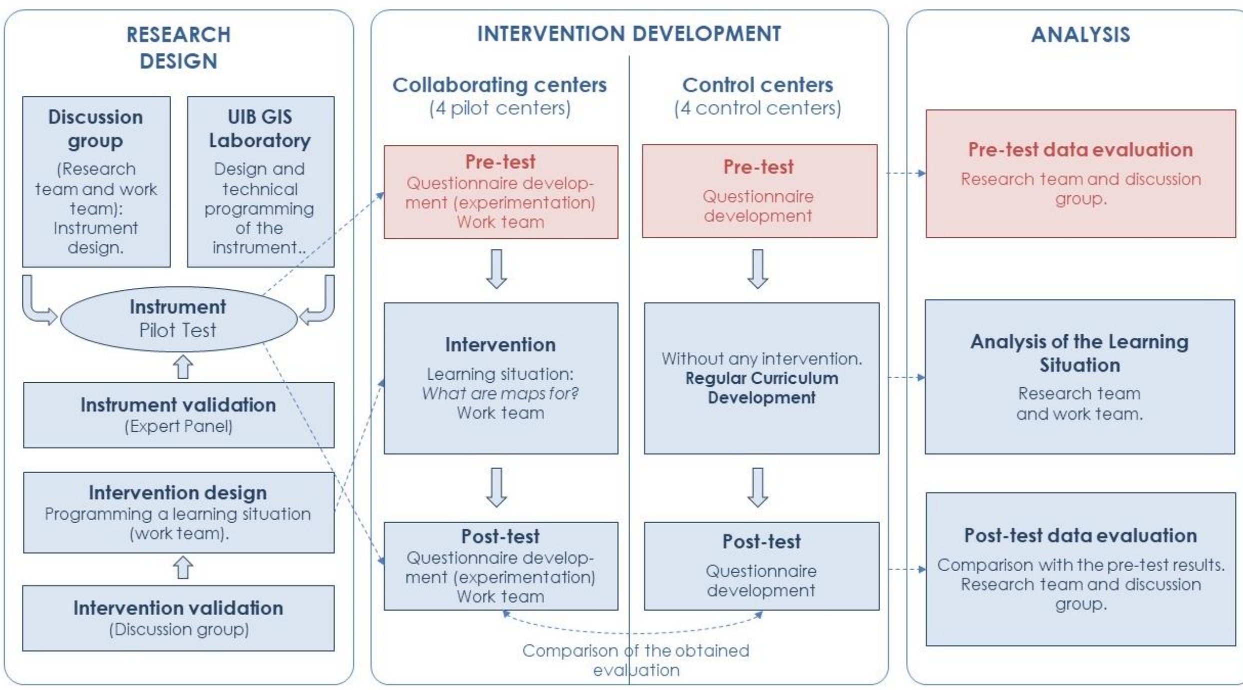

Figure 1. Flowchart of the methodological development of the project. Source: Prepared by the authors.

The findings contributed by this article correspond to the sections on spatial competence and location of elements on the map. Spatial competence was diagnosed by including 9 questions associated with the dimension of large units on Earth, modeled on the work of Battersby and Montello (2009). The students were asked to mentally compare, without a reference map, the area of 9 regions with that of Spain; however, unlike the mentioned study, they only had to indicate whether each of the regions was larger or smaller than Spain. This variation was introduced in the instrument's validation phase, given how difficult the original proposal was for secondary education students who do not yet have the appropriate mathematical competences to perform this type of operation. The list of spatial units consisted of 7 countries (Russia, Sweden, Austria, Italy, North Korea, Japan and South Africa), one continent (Antarctica), and one island (Greenland). The territorial units were chosen according to the following traits: diversity of sizes, variety of distance from Spain, and different latitudes (Table 1). Theoretically, and in the light of previous results, regions that are clearly much larger than Spain should be easier to recognize than smaller ones, and much more so than similar ones, and it should also be easier to estimate their areas. The closest regions, in the European area, should be easier to identify than those that are more distant, since students are more familiar with the map of Europe. Regarding units at higher latitudes, there is greater distortion as to their areas in commonly used map projections and, therefore, the study was performed with the certainty that students would overestimate their areas.

Criteria	Territorial units		
Size in comparison with Spain	*Small* Austria, North Korea	*Similar* Sweden, Italy, Japan	*Large* Greenland, Russia, South Africa, Antarctica
Distance	*Europe* Austria, Sweden, Italy, Russia		*Other continents* Greenland, South Africa, North Korea, Japan, Antarctica
Latitude	*High* Sweden, Greenland, Antarctica		*Mid* Austria, Italy, North Korea, Japan, South Africa

Table 1. Characteristics of the selected territorial units. Source: Prepared by the authors.

After they had estimated the dimensions of the 9 territorial units, the students located them on the map (PLD) using the online cartographic instrument prepared for such purpose. This was accomplished using a similar methodology to the one described in other studies (Torrens, 2001). However, our instrument automatically generated a double assessment once the students had located the unit on the map. Firstly, it indicated whether the answer or chosen location was correct or not. Secondly, if the answer was wrong, it measured the distance in kilometers between the entered location and where it is actually located. This was used to quantify the magnitude of the participant's error.

In this study, the data collected have been used to analyze three aspects. In the first place, the results of the PLK test, both the right and the wrong answers and the mean deviation distance of the locations provided for each of the 9 places. Then, the answers to the spatial competence exercise on the estimation of dimensions. As this was a two-choice question (larger or smaller than Spain), and to avoid counting randomly produced correct answers, two values were considered: those obtained from the entire student sample and those given by the students who had correctly placed the unit in the PLK test. This showed that they were indeed familiar with the examined element and, therefore, better able to estimate its area. Finally, a comparative analysis of the two variables was performed using multivariate exploratory cluster analysis to find spatial patterns for interpreting the results. This methodology is similar to that used in other studies (Bednarz and Lee, 2011; Binimelis et al., 2023). The cluster analysis was performed using the *ArcGIS Pro 3.2 multivariate clustering* tool, which finds natural clusters of entities based solely on input feature attribute values. In the design of the analysis, the 9 territorial units were entered as entities, and two variables were considered: percentage of correct PLK answers, and area estimate by students who had correctly located the unit (Figure 5). The k-means clustering method was used because it is faster and adapts well when the volume of input data is not excessively large, as is our case.

ArcGIS Pro 3.2 software was also used to prepare all the maps in the study. The resulting percentages of correct answers, both in the PLK test and in the area estimate of territorial units, were mapped using cartodiagrams (Figures 2 and 4). The error introduced in the PLK test was represented using a proportional symbols map (Figure 2).

The results have been analyzed considering two of the sociodemographic variables consulted in the test: gender and travel experience. This is because students who travel more often are expected to obtain better test results due to greater geographic knowledge, while also being an indicator of their family's socioeconomic status (Torrens, 2001).

3. Results

The main results yielded by the research are set out below, arranged into three sections, each of which corresponds to the different analyzed aspects: PLK assessment, estimation of areas, and comparative analysis of the two variables.

3.1 PLK assessment

In the place location knowledge (PLK) test, the participating students show limited knowledge. Only 43.55% of the responses they gave were correct. According to gender, the scores of male students were higher (50.71%) than those of female students, who only achieved 37.27% of correct answers (Table 2), a fact that reveals a powerful gender bias as regards the analysis of PLK. This difference can be considered significant because according to the variance analysis, using a 95% confidence level, the resulting F value (16.67) is above the critical value of F (3.8), which leads to the rejection of the null hypothesis.

On the other hand, there is a positive correlation between the number of journeys and the percentage of correct answers in the PLK test. Students who reported to have made 6 or more journeys obtained a mean score of 59.02%. By contrast, the scores of students who had made fewer than 3 journeys were lower (38.91%). In the light of these results, traveling can be assumed to have a certain impact on students' assessment. To corroborate this thesis, a variance analysis was performed based on the data reported as total journeys, yielding an F value (9.39) that was higher than the critical value (3.02), which allows the rejection of the null hypothesis. Thus, it could be stated that traveling has a positive impact on students' geographic literacy. However, certain differences are observed when comparing the results of journeys made inside Spain and those to other countries, which entails the need for further explanation of such statement. The different scores for each of the journeys inside Spain groups are statistically significant, the variance analysis yields an F value (8.12) that is above the critical value (3.02). On the other hand, the differences in scores for journeys to other countries cannot be regarded as statistically significant, since the variance analysis does not allow the rejection of the null hypothesis, the F value being 0.76 and the critical value 3.03. Consequently, local traveling has a greater influence than international journeys in the assessment of PLK (Tables 2 and 3).

Gender	Average of correct answers. Area estimation	Average of correct answers. PLK	Participants
Male	68.65%	50.71%	140
Female	62.02%	37.27%	127
Other	58.33 %	18.05 %	8
Mean	65.29 %	43.55 %	275

Table 2. Main test results according to gender.
Source: Prepared by the authors.

	Journeys inside Spain	Journeys to other countries	Total journeys
Fewer than 3	40.25%	43.21%	38.91%
3 to 5	54.04%	45.50%	49.44%
6 or more	61.90%	66.66%	59.02%

Table 3. PLK test results according to number of journeys made. Source: Prepared by the authors.

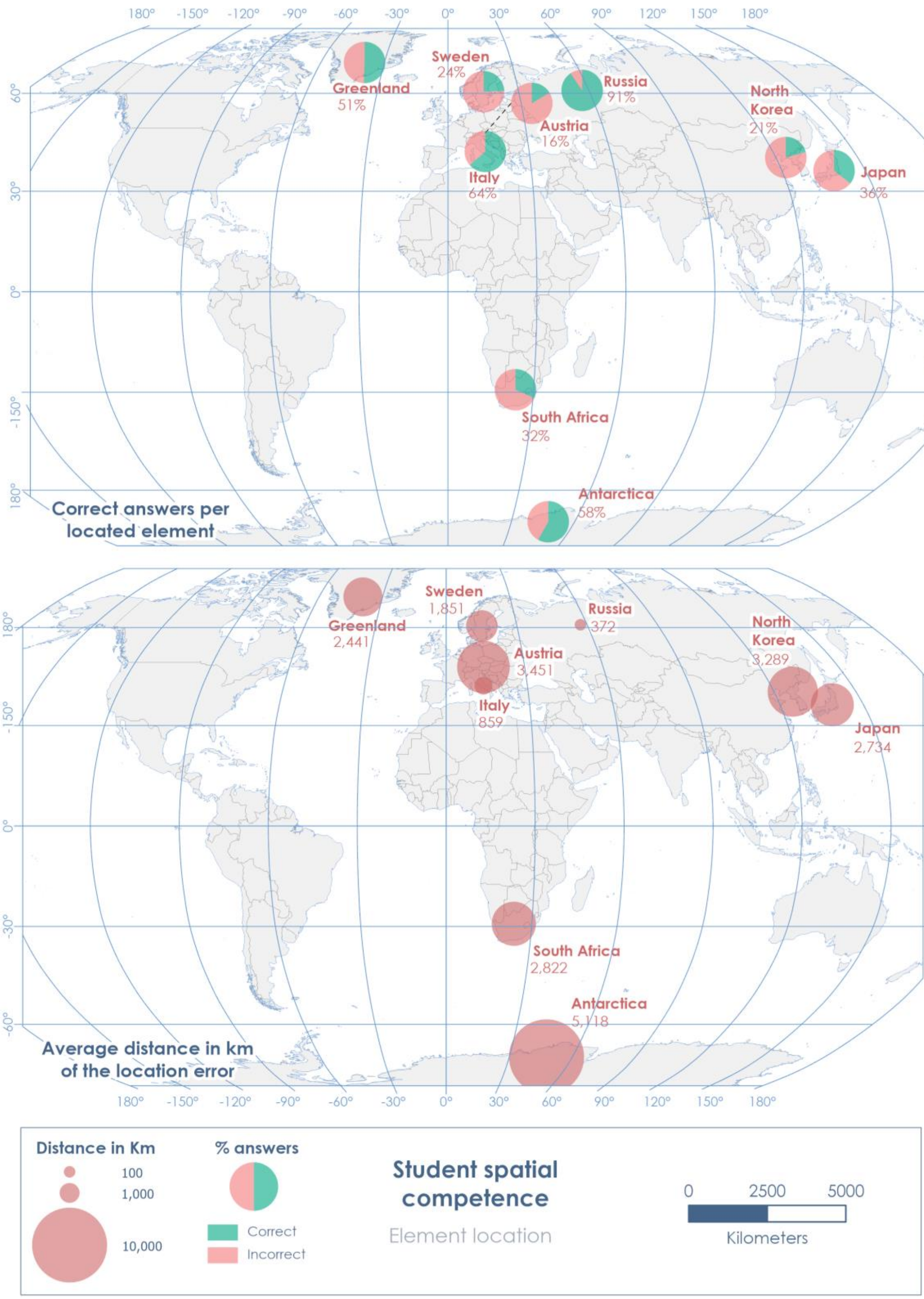

Figure 2. PLK test results for each of the territorial units. Source: Prepared by the authors.

The territorial units with a higher percentage of correct locations were Russia (91%), Italy (64%), Antarctica (58%) and Greenland (51%). Indeed, those four were the only ones that obtained an average above 50%. In the case of Russia, this could be explained by different factors, such as its large area or high presence in the media, especially as a result of the Russia-Ukraine War. Italy, on the other hand, has different connotations, and the main factor that makes it easy to locate for Balearic students is its geographic proximity in the western Mediterranean, although the fact that the Italian peninsula is an easily identifiable territory could also play a role in this regard. As for Antarctica and Greenland, their profiles are similar and both regions can be considered large terrestrial units, the former a continent, the latter the largest island (Figure 2).

All the remaining countries obtained values below 50%, with Austria obtaining the lowest results (16%) despite being a European Union Member State. Its small size, the fact that it is a landlocked inland region -which adds difficulty to its identification-, or possible confusion with Australia could be some of the reasons for these low percentages of correct answers (Figure 2).

To further contextualize the PLK test results, the tool automatically calculated the distance that each participant diverted from the real location of the element that was to be placed. The results obtained for the variable are inversely proportional to the level of success: the lowest values show a higher degree of successful location whereas the highest show greater deviation from the correct location. As with the former indicator, the most positive values were obtained by Russia, with a deviation of only 372 km. On the other hand, the most negative value was reported for Antarctica, with a mean distance error of 5,118 km, despite being one of the regions with the highest number of correct answers. Students who cannot properly place the continent make a greater mistake regarding its location. In general, the mistakes made by students are less serious in units that are closer than in those that are farther.

The two variables of PLK that are analyzed in this section, percentage of correct answers and entered distance of error, are negatively correlated; besides, the distance of error is lower for units that obtain a higher percentage of correct answers in their location (Figure 3). There are only two exceptions to this rule. One of them is Sweden, which yields very low percentages of correct location (24%), while the mean distance of error entered is relatively low as compared to other units (1,851 km). This exception reveals that participants do not accurately know its location or confuse it with that of other countries such as Switzerland; however, they are aware that it is a European country and, hence, the deviation entered when placing it is lower than the one for the rest of the units. The other exception is the Antarctic continent, whose location is known by 58% of the students, albeit with very high levels of deviation among those who are not aware of its exact location, as this unit is very far away from the rest.

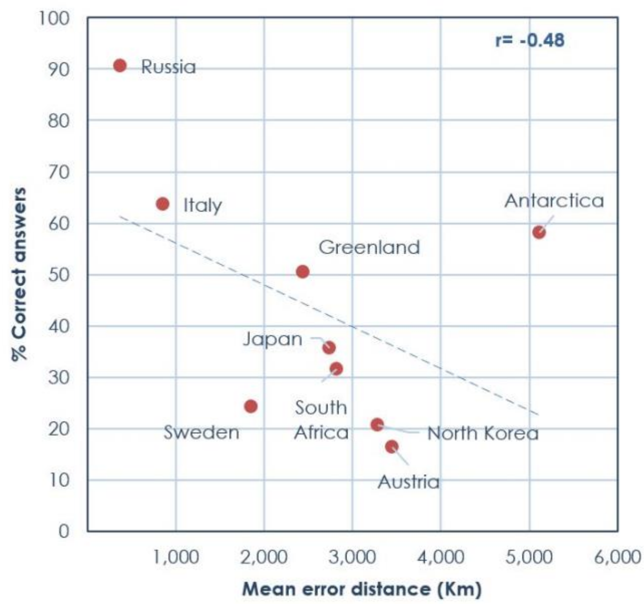

Figure 3. PLK test scatter plot. Source: Prepared by the authors.

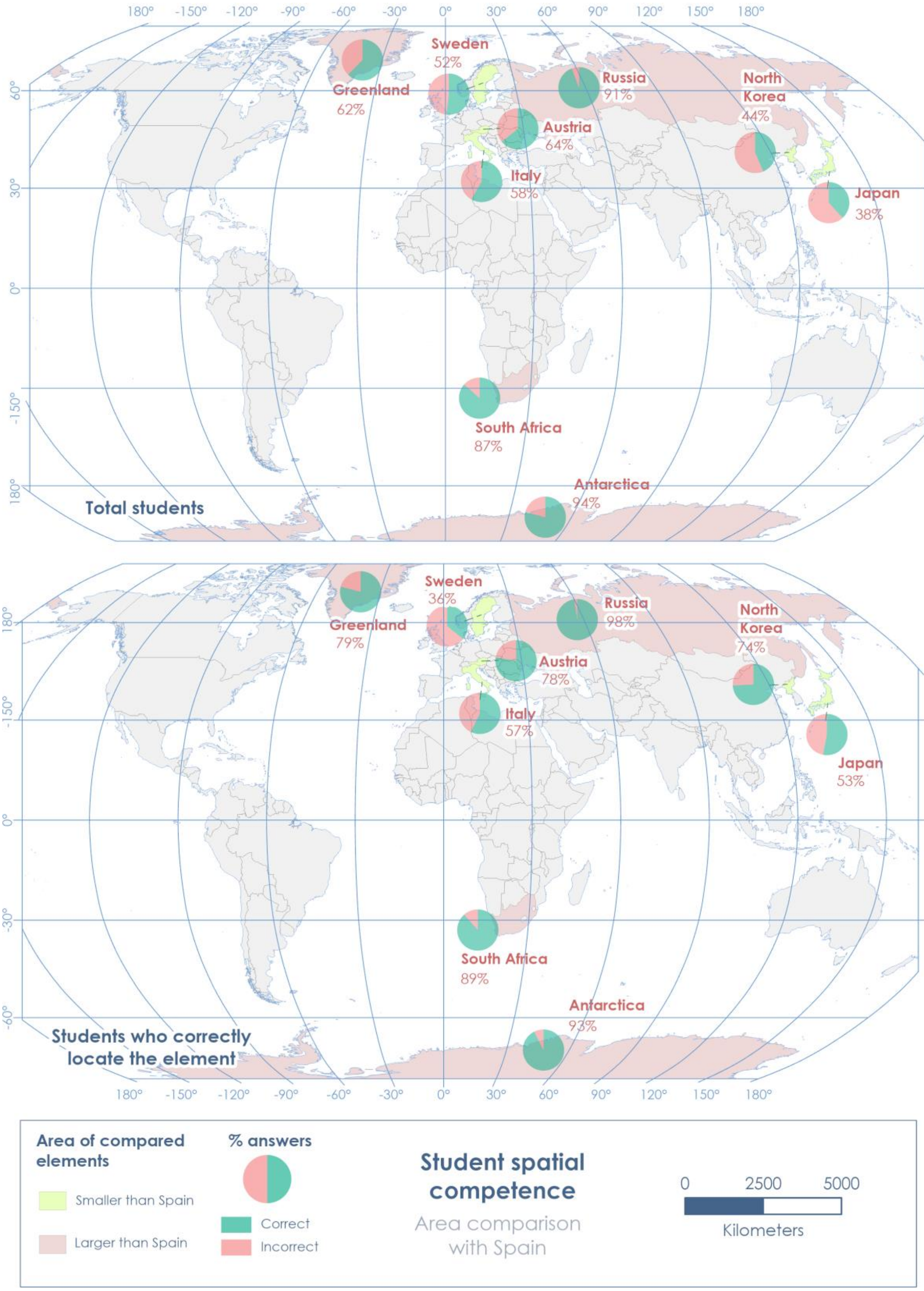

Figure 4. Results of the area estimate test for each of the territorial units. Source: Prepared by the authors.

3.2 Area estimate

The average of correct answers in the territorial units' area estimate test reveals slightly better results (65.29%) than those obtained in the PLK assessment. This relative improvement could stem from the fact that there are only two possible answers, larger or smaller than Spain, which makes luck play a significant role. According to gender, male students obtained slightly higher results (68.65%) than female students 62.02% (Table 2). The analysis of variance, with a 95% confidence interval, also allows the rejection of the null hypothesis, since the F value (12.11) is greater than the critical value (3.87).

In terms of journeys made (Table 4), there is a trend towards better results when there is a larger number of journeys. Nevertheless, these differences are not as clear as in the PLK study. The analysis of variance does not allow the rejection of the null hypothesis (F=0.93, critical value of F = 3.02). Consequently, the results in this regard are inconclusive.

	Journeys inside Spain	Journeys to other countries	Total journeys
Fewer than 3	64.56%	65.29%	64.48%
3 to 5	66.66%	64.55%	66.11%
6 or more	72.22%	72.22%	68.40%

Table 4. Results of the area estimate test according to journeys made. Source: Prepared by the authors.

In order to improve the interpretation of the area estimate test, two differentiated results are provided. On the one hand, the percentage of correct answers from the total of respondent students and, on the other hand, the same percentage from students who, in turn, had correctly located each of the territorial units (Figure 4). The latter solution allows us to take into account only the estimates of students who identify the region, eliminating guesswork estimates made by students who do not recognize it.

Those territorial units whose area is clearly larger are also the ones that achieve a higher average percentage of correct answers: Russia (98%), Antarctica (93%), South Africa (89%) and Greenland (79%). Countries with a clearly smaller area, such as Austria (78%) or North Korea (74%), also yield quite high percentages of correct answers. Meanwhile, the other three elements under analysis, those whose area is similar to Spain's (Figure 5), show a lower average percentage of correct answers: Italy (57%), Japan (53%) and Sweden (36%). Of the three, the case of Sweden is the most remarkable, as it is the only one with a negative value. This can be explained by the confluence of two factors: on the one hand, it is the territory whose area is closest to that of Spain, as Sweden covers 446,011 km^2 and Spain 506,030; on the other hand, this example may be influenced by the respondents' perception of areas located at high latitudes, with the distortion caused by the Mercator projection that is commonly used for maps.

3.3 Comparative analysis. PLK and area estimate

Is there any type of relationship between the results obtained for the two variables: PLK and area estimate? This conjecture or hypothesis has been examined by estimating and developing several statistical tests. Accordingly, there is a poor relationship between the results of both tests, as the Pearson correlation coefficient is only 0.43. This means that the units that reflect larger percentages in location are not always the ones to obtain better area estimates. Because of this, an exploratory cluster analysis was designed to help define whether there were certain patterns to further examine this relationship. The analysis yielded 4 groups of territorial units, each of them with different behaviors and characteristics (Figure 5).

One group consists of the units that cover a vast extension of land, which obtain high values in both of the study variables (Russia, Antarctica and Greenland). The large area factor seems to be decisive both in placing them and in estimating their area in relation to Spain (cluster 4).

On the other hand, cluster 2 only includes Italy, with correct answer values that are similar and relatively high in both tests, around 60%.

Cluster 1 includes three countries with low percentages of correct answers in the PLK test and relatively high values in area estimate (Austria, North Korea and South Africa).

The last cluster consists of countries that score low in the two variables (cluster 3): Japan and Sweden. Both obtain low percentages in location, under 40%, and also in area comparison.

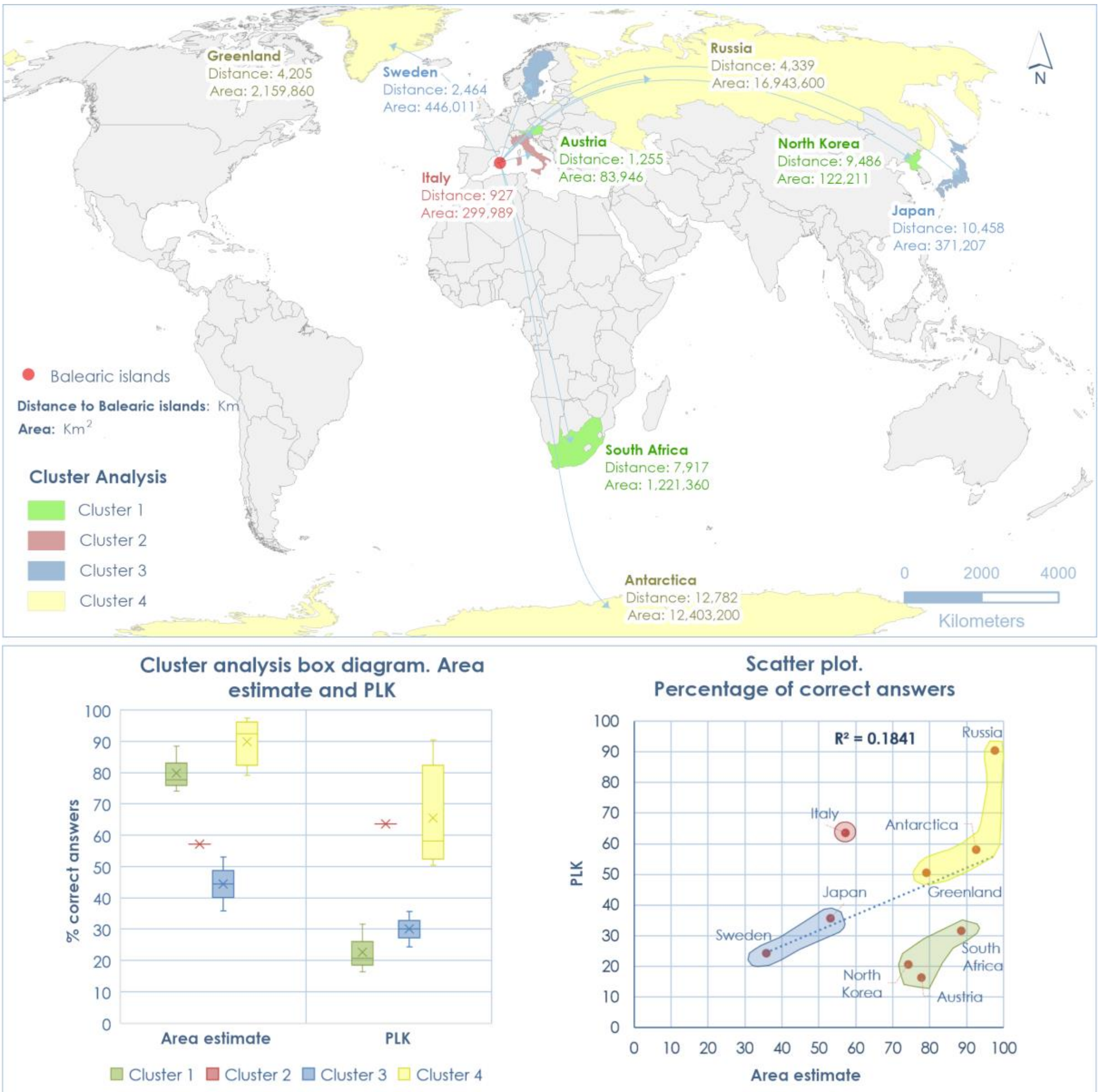

Figure 5. Cluster analysis: percentages of correct answers in the PLK test and percentage of correct answers in area estimate (students who correctly located the element). Source: Prepared by the authors.

4. Discussion of results

Although there are many studies on geographic literacy, their methodological differences hinder the systematic comparison of results. For example, their tests do not use the same regions and countries. Despite this, it can be affirmed that the global results of the PLK test carried out in this study (43% of correct answers) are comparable to the ones obtained in other similar ones. Thus, in the test performed with Irish secondary education students (Torrens, 2001), 15 points out of 37 were averaged out, accounting for 40.5% of correct answers. Another similar work, promoted by National Geographic in the USA, assessed 510 American students between the ages of 18 and 24, who were asked questions about knowledge of the world, yielding a result of 54% of correct answers (Zhu et al., 2016). In general, most studies highlight the low level of geographic literacy of their respondents. For example, a study carried out in Turkey among secondary education students marked their ability to locate climatic areas of the world as mediocre (Dal, 2008).

One of the most important factors influencing place location knowledge, according to our data, is the dimension or size of a territorial unit. The largest regions are more easily identifiable than the smaller ones. This hypothesis has been tested in other PLK studies (Torrens, 2001; Thomas and Willinsky, 1999). In addition to area, Torrens (2001) pointed out other factors as determinants of success in locating the element, such as presence in the media or being in island locations. By way of example, in his study, Australia, a unit in which several of these factors converge, obtained one of the highest percentages of correct answers (94.2%). Our study has yielded similar results in the location of Russia, Greenland or Antarctica.

Places that are close to the area of study and, sometimes, with strong cultural ties, are also among the most easily recognizable (King and McGarth, 1988; Reynolds and Vinterek, 2016; Waddington and Shimura, 2019). In our case, Italy seems to confirm this characteristic, with PLK scores that are above average. By contrast, this does not apply to other European Union member states such as Austria or Sweden, with slightly different cultures and lower scores. On the other hand, the most distant locations, such as North Korea, Japan and South Africa, also obtain under-average PLK values. The main reason for this could be that the curricula and teaching methods allot little time for the acquisition of knowledge about territories in remote regions, focusing more on the regional or local environment (Dal, 2008).

While assessments concerning the location of elements are generally poor, this is not the case with size comparisons among different regions or countries. In this, the results obtained in our study are better. However, as was the case with PLK, the variety of methodologies used in similar studies hinders the systematic comparison of data. The main purpose of most studies on area estimates is to determine the present and past influence of cartographic projections on the construction of cognitive maps of the world. Battersby and Montello (2009) carried out their research with university students, using a module for comparing areas. Their results were quite positive, reporting a correlation of 0.82 between predicted and actual values. Lapon, Ooms and De Maeyer (2020) obtained almost identical results, with a correlation coefficient of 0.806 between actual and predicted values, while another analysis conducted with young people aged between 12 and 40 yielded a correlation of 0.885 (Lapon et al., 2019). In our research, the respondents estimated whether the areas of the selected territorial units were larger or smaller than Spain. Students in the Balearic Islands averaged 65.29% of correct answers in this part of the test. Methodological variations could be introduced in future replications in an attempt to tally the appropriateness of the test with secondary education students' competencies, in turn reducing the distortions arising from guesswork in binary response questions.

Indeed, in our study, the units that score the highest are those that are clearly larger or smaller than Spain, while the regions that achieve the lowest scores are those whose areas are more similar in size. Most of the consulted studies conclude that there is a low correlation between overestimating a region's area and greater latitude. Therefore, map projection does not seem to have much relevance to area estimation (Battersby and Montello, 2009; Lapon et al., 2019). According to the findings of this research, Sweden achieves the lowest rate of correct answers (36%), which could contradict this hypothesis but should in no case be regarded as a significant result because there are other factors that could influence it, such as it being the unit whose area is the most similar to Spain's.

In terms of gender, the differences observed in PLK scores or in area estimates are repeat results in a large part of the consulted studies: male students rank higher than female ones. Torrens (2001) describes a 6-point difference between boys and girls. Raento and Hottola (2005) analyzed the differences in map knowledge in secondary education students and also reported noticeable differences according to gender. These gender-based differences in spatial abilities have been broadly addressed in academic literature and can be basically summarized in two aspects (Torrens, 2001): biological factors (brain lateralization and hormonal differences) and sociocultural factors (cultural influences and stereotypes). However, these differences are only important in PLK tasks because when other variables associated with geographic literacy are analyzed, the differences become smaller and less significant (Bednarz and Lee, 2011; Bednarz and Lee, 2019). The analysis provided in this study is aimed at aspects that are clearly related to spatial competence, which is why it yields significant differences according to gender. Nevertheless, the project that frames this research examines other geographic literacy parameters and, therefore, future work will allow a more in-depth study of the topic as well as further explanation of the mentioned statements.

Certain studies have highlighted the existence of a relationship between travel experience and an improvement in spatial thinking (Bednarz and Lee, 2019). In this regard, there are authors who have introduced the journey variable to characterize PLK (Torrens, 2001; Raento and Hottola, 2005). Torrens (2001) confirmed that traveling locally, inside Ireland and to the United Kingdom, and journeys around Europe correlated positively with PLK, simply differentiating between students who had traveled and those who had not. The results provided in this research are more specific with the aim of improving said relationship. Thus, the number of journeys made by each student has been counted and evidence has been provided that students who travel more often, especially locally, inside Spain, score higher in the location test. Some authors claim that experience and one's relationship with the environment model spatial intelligence because of the interrelationship between "practical" space and "represented" or cognitive space (Sarno, 2012). In this regard, it could be said that the experience of traveling contributes to the building of more solid cognitive maps in students, which is reflected in their ability to locate units on a map.

5. Conclusions

This study is framed in the area of research on secondary education students' geographic literacy. Its main contribution is the analysis of spatial competence, understood as the ability to read, understand and use maps, based on the examination of two parameters: place location knowledge (PLK), and area estimate and size comparison between different regions around the world. There are similar studies based on other geographic contexts, although they always address both topics separately rather than jointly. Another novel aspect of this research is the use of an online instrument to carry out the tests, which not only provided information on whether students' answers were correct but also calculated the error in distance in the entered locations.

Firstly, the final results show that students in the Balearic Islands have a poor background in the assessed abilities, as had already been reported in other similar studies conducted around the world. In the light of the data, it seems that the increasingly common use of maps through online applications has not resulted in an improvement in geographic knowledge. The values obtained are quite similar to those reported in other studies, even if they were carried out many years earlier and in different learning environments. The PLK test results lead to the conclusion that students can only clearly identify the closest territorial units, those within the Mediterranean area, and the largest. In the rest of the cases, their placement skills are poor. As regards area estimates, the scores reported are slightly higher, especially when comparing Spain with much larger or much smaller areas. However, there is no direct relationship between the two abilities: the regions that are most easily located are not always the ones that obtain the highest area estimate values nor the other way around. Actually, the answers depend on other geographic factors such as area, closeness to the area of study, position on the coast or inland, etc.

Secondly, there is evidence that certain personal factors could affect students' level of spatial competence, such as gender or travel experiences. Male students show greater abilities than female ones in locating elements on the map and estimating areas. Moreover, the number of journeys made by each student has an impact on their acquisition of spatial competence, be it because traveling involves improvement in the development of their abilities to read and interpret maps or because it is an indicator of families' socioeconomic status and the greater availability of resources that it entails.

Finally, it should be noted that the studies performed allow us to progress in the diagnosis of geography teaching in secondary education and in detecting problems associated with our society's geographic literacy. This will enable the design of teaching strategies for the improvement of students' geographic literacy and the strengthening of their spatial competence in the following phases of the project that this research is part of.

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