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NETWORK RESEARCH ON THE PROFICIENCY OF SPATIAL THINKING IN UNDERGRADUATE GEOGRAPHY COURSES: initial approaches

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ABSTRACT

This article is the result of a network research that aimed to identify to what extent the undergraduate courses in Geography from five brazilian Higher Education Institutions (HEIs) contribute to the spatial thinking proficiency of their students. This investigation was established through applications of the instrument named Spatial Thinking Ability Test (STAT), elaborated by Lee and Bednarz (2012), for beginners and final-year undergraduate students of the Geography course, preferably, undergraduates. The application focused on these two groups, and was intended to identify knowledge regarding to spatial thinking throughout the training of future geographers. As a result, the global analysis of the data indicates a very modest difference in performance between first and fourth-year undergraduate students in Geography and a lower than expected performance in terms of the percentage of correct answers of both two groups in competences assessed through problem-situations that we understand to be easier. All this investigative effort was based on the recognition that spatial thinking is one of the most fundamental intellectual conditions for, subsequently, students become to produce the geographical interpretation of problematic situations.

KEYWORDS

Geography Teaching, STAT, Teacher Training, Spatial Intelligence.

PESQUISA EM REDE SOBRE A PROFICIÊNCIA DO PENSAMENTO ESPACIAL NOS CURSOS DE GRADUAÇÃO EM GEOGRAFIA: primeiras aproximações

RESUMO

Esse artigo é resultado de uma pesquisa em rede que teve como objetivo identificar em que medida os cursos de graduação em Geografia de cinco Instituições de Ensino Superior (IES) brasileiras contribuem para a proficiência do pensamento espacial dos seus estudantes. Essa investigação se estabeleceu a partir de aplicações do instrumento denominado Teste de Aptidão do Pensamento Espacial (Spatial Thinking Ability Test - STAT, em inglês), elaborado por Lee e Berdnaz (2012), para graduandos iniciantes e finalizantes do curso de Geografia, preferencialmente, licenciandos. A aplicação focada nesses dois grupos, destinou-se a identificação de conhecimentos referentes ao pensamento espacial ao longo da formação de futuros geógrafos. Como resultado, a análise global dos dados indica uma diferença de performance bastante modesta entre alunos do primeiro e do quarto ano da graduação em Geografia e um desempenho inferior ao esperado em termos de percentuais de acertos dos dois grupos em competências avaliadas através de situações-problema que entendemos como mais fáceis. Todo esse esforço investigativo assentou-se no reconhecimento de que o pensamento espacial é uma das condições intelectuais fundamentais para que, posteriormente, os alunos venham produzir a interpretação geográfica de situações problematizadas.

PALAVRAS-CHAVE

Geography Teaching, STAT, Teacher training, Spatial intelligence.

Introduction

This work aims to identify the contribution of geography courses to the proficiency of students' spatial thinking. The analyzes contained herein were developed based on the question that guides this research: to what extent have undergraduate courses in geography contributed to the proficiency of spatial thinking to favor students in the development of geographic interpretation throughout their initial training? All this investigative effort was based on the recognition that spatial thinking is one of the fundamental intellectual conditions so that, later, students can produce the geographic interpretation of problem-solving situations (RICHTER, 2011; CASTELLAR, 2017; CASTELLAR and JULIAZ, 2017; DUARTE, 2017, PEREIRA, 2018; ROQUE ASCENÇÃO, VALADÃO and ASSIS, 2018).

Therefore, we chose to develop this network research, which lasted two years (2019-2021), through face-to-face and remote meetings, in which the stages of development of this study and its respective application in all the participating institutions were established. The selection for an investigative didactic approach taking on the features of network research was not random, revealing the most significant concern of the authors: the identification of aspects related to the knowledge of spatial thinking in the work of initial teacher training in geography undergraduates, especially in the teaching field. To take part in this research, prominent professors in teacher education working in eight major Brazilian universities were invited[1]. For different reasons, from this first group, five institutions agreed upon and remained in the research, namely: the State University of Rio de Janeiro (UERJ), Federal University of Tocantins (UFT), Federal University of Goiás (UFG), Federal University of Pelotas (UFPel) and Federal University of Minas Gerais (UFMG). The coordination of the research was under the responsibility of Professor Ronaldo Goulart Duarte, who, in his doctoral research (DUARTE, 2016), carried out a deep immersion in the theory of Spatial Thinking.

Establishing a research methodology, understood here in a sense proposed by Minayo (2002, p. 09) as "the way of thought and practice exercised in the approach to reality," has been, since the project's elaboration, a concern, and a quest above all due to the collaboration in the network research between the universities involved. The path followed in the two years of an execution revealed that investigating network is not a simple task since each context has peculiarities, rhythms, and different working conditions. Establishing a compass on the research agenda, respecting singularities, was a challenge. In this effort, the adoption of collaborative planning of research actions proved to be a delicate strategy, albeit very fertile, concerning learning arising from joint research. The support of communication and information technologies, particularly the internet and its multiple tools, ensured an accurate approximation between researchers so that discussions, decisions, and data analysis were possible.

The initial step of our research was based on the Spatial Thinking Ability Test (STAT), developed by Lee and Berdnaz (2012). At first, the test was administered to freshmen students, preferably those intending to attend a degree in geography teaching. The same test was also administered to undergraduate students ate the final year of their course, once again with major focus on those being prepared to be teachers. There were 289 tests, with 189 tests administered to first year students and 100 tests to fourth year students, considering all Higher Education Institutions (HEIs) involved in this research. After this task was finished, we performed the tabulation of the data to compare the institutions involved and, thus, infer a profile of Brazilian geography newcomers and senior students, concerning the development of spatial thinking.

Concerning this material, the data and results presented in this article refer to the set of partner universities, structured from graphs relating to student responses about the STAT, which allowed us to understand the convergent and divergent elements concerning the development of the spatial thinking of newcomers and senior students from the HEI involved in this research. However, it is worth noting that the results analyzed here are only part of the more extensive set

[1] The initial idea of the research began with a group of researchers who participated in the X Colloquium on Cartography for Children and Schoolchildren and the 1st International Meeting of School Cartography and Spatial Thinking, held at the University of São Paulo (USP), from the 9th to the 12th of July.

of data collected by this investigation and will be presented at another moment in the near future.

The first part of the text is dedicated to presenting the HEIs that are part of this study, briefly detailing the origin of the courses and their curricular structures. In the second part, we will present the profile of the students taking part in the research, based on the socioeconomic questionnaire administered to these subjects; and in the third part, the global analysis of the students' responses is presented, including the data for the first and fourth year of the HEIs.

The Higher Education Institutions taking part in the research

As previously presented, five HEIs took part in this research and served as a framework for the analysis of the spatial thinking proficiency of undergraduate geography students, both newcomers and last-year students. As these institutions have their own characteristics and curricular structures, it is considered pertinent to briefly present the background of these HEIs, the number of enrolled students, the workload for the completion of the degree, and the subjects linked to the cartographic knowledge/content present in the curriculum of each course.

The State University of Rio de Janeiro was founded in 1950, has 16 campuses and external units, 43,000 students, 2,800 professors, distributed in 90 undergraduate courses, 63 masters, and 46 doctoral courses. The geography course is offered in three units of UERJ: in the campus of the Faculdade de Educação of Baixada Fluminense, in the municipality of Duque de Caxias; on the campus of the Faculty of Teacher Training, in São Gonçalo; and in the Maracanã campus, in Rio de Janeiro. Only in the latter is the course offered in teaching and bachelor's degrees. In the other two units, the course is offered only for the teaching degree.

In this research, the participating students were the ones enrolled in the geography course on the Maracanã campus, located at the Geography Institute (IGEOG). The course is offered in the afternoon/evening shifts, enabling many students to combine working hours with regular class attendance. In each of the qualifications, the course is expected to be finished after nine periods. It takes 3,120 hours for a bachelor's degree and 3,195 for a teaching degree. The student is given the possibility of taking the qualifications in parallel due to the considerable number of subjects common to the two flowcharts, but it is not feasible to complete both qualifications in a period of less than five years. Currently, there are 451 students regularly enrolled and active in the two undergraduate courses in Geography, as the majority choose to complete both.

The current curriculum is organized from the 2010 Pedagogical Course Project (PCP), and, in the case of the teaching degree, it has not yet been adapted to the CNE Resolution 2/2015 due to an extensive set of complications. In the undergraduate course curriculum, there are four subjects linked to Cartography, geotechnologies, and representations of space, totaling 360 hours of workload: Basic and Thematic Cartography (90 hours - first period); Spatial Representation (60h - third period); Remote Sensing applied to Geography (90h - fourth period); Geoprocessing I (120h - fifth period).

The Federal University of Tocantins (UFT) has seven campuses with 18 thousand students, 1,104 professors, distributed in 64 undergraduate, 39 masters, and nine doctoral courses. The geography course is offered on two campuses: Araguaína, which offers a teaching degree only, and Porto Nacional, with teaching and bachelor's degrees.

The students who took part in this research were the ones enrolled in the undergraduate course in Geography teaching in Araguaína or in Porto Nacional offered in the night shift. The course's workload, both in Araguaína and Porto Nacional, is scheduled to take place in eight periods, with Araguaína totaling 3,225 hours of the course and at Porto Nacional 3,090 hours. The degree in Araguaína has the offer linked to the 2018 PCP, while Porto Nacional has the offer of the PCP course approved in 2013, which reveals that the curriculum was not adequate to the CNE Resolution 2/2015.

The degree in Porto Nacional has four curricular components related to Cartography, geotechnologies, and representations of space, totaling 240 hours of workload and distributed as follows: Cartography (60 hours - first period); Thematic Cartography (60 hours - second period); Geoprocessing and Remote Sensing Applied to Teaching Geography (60 hours - sixth period); Cartography Teaching Practice (60 hours - seventh period).

In Araguaína, the curriculum has three curricular components related to Cartography, geotechnologies, and representations of space, totaling 225 hours of workload and distributed as follows: Cartography (75 hours - second period); Geotechnologies (90 hours - third period); Cartography and teaching (60 hours - fifth period).

The Federal University of Goiás (UFG) was founded in 1960 and has 102 undergraduate courses, 3 thousand professors, and 25 thousand students, distributed in two regions, Goiás and Goiânia. In the latter, UFG has the Colemar Natal e Silva Campus (Universitária Square) and the Samambaia Campus. In addition to undergraduate courses, UFG offers 78 post-graduate courses, including master's, doctoral and professional master's degrees, with more than 4,200 students.

The UFG participants in this research were students from the undergraduate course in Geography teaching from Goiânia, offered in the morning and in the evening by the Institute of Socioenvironmental Studies (Instituto de Estudos Socioambientais - IESA), created in 1968, with qualifications for bachelor's and teaching degrees and which has approximately 360 enrolled students. IESA also has a Post-Graduate Program in Geography (PPGeo) - master's and doctorate - which covers three lines of research, including one relating to studies in the field of geographic education.

To complete the UFG teaching degree in geography, students must complete a total workload of 2,960 hours, based on the PCP in force since 2015, but which was not adequate to the CNE Resolution 2/2015. Regarding the cartographic knowledge present in the training of students, this curriculum offers the following mandatory subjects: Cartography I (64 hours - first period) and Cartography II (64 hours - second period), totaling 128 hours; and as elective subjects: School Cartography (64 hours - seventh period), Geoprocessing I (64 hours - fourth period), Geoprocessing II (64 hours - fifth period), Remote Sensing I (64 hours - fourth period) and Remote Sensing II (64 hours - fifth period).

The Federal University of Pelotas (UFPel) was created in 1969, comprising the Faculty of Agronomy, Veterinary Science, Domestic Sciences, Law (founded in 1912), Dentistry (1911) - the last two belonging to the Federal University of Rio Grande do Sul, and the Institute of Sociology and Politics (ISP), founded in 1958. The university currently has six campuses: Capão do Leão Campus, Porto Campus, Centro Campus, Norte Campus, Fragata Campus, and Anglo Campus, where the Rectory is located, and other administrative units. It has 22 academic units and 96 on-site undergraduate courses, 66 of which are bachelor's degrees, 22 teaching degrees, eight technologists, and three online undergraduate courses, in 117 centers.

UFPel's Teaching Degree in Geography was created in 1989, and it houses the teaching and bachelor's degrees today, both evening courses. Students enrolled in the teaching degree course took part in this research. To complete this course, students must complete a total workload of 3,260 hours, having as reference the 2018 PCP, appropriate to the CNE Resolution 2/2015. Regarding the cartographic knowledge present in the training of students, there are three compulsory subjects linked to Cartography and Geotechnologies: Basic Cartography (60 hours - first period); Thematic Cartography (60 hours - second period), and Geotechnologies (60 hours - third period), totaling 180 hours of workload. In optional subjects, Tactile Cartography (60 hours) and Remote Sensing applied to Geography Teaching (60 hours) are also offered, totaling 120 hours of workload.

The Federal University of Minas Gerais (UFMG) was created in 1927 through the meeting of higher schools of Law, Medicine, Engineering, Dentistry, and Pharmacy. Its federalization took place in 1949, and only in 1965 it received its current name. It has approximately 34 thousand undergraduates and more than 10 thousand graduate students distributed, respectively, in 91 undergraduate, 90 masters, and 69 doctoral courses.

The geography course was created in 1939 in the teaching modality. Currently, the course is allocated at the Geosciences Institute, offering a teaching and bachelor's degree in the morning and a teaching degree in the evening. Students enrolled in the teaching degree took part in this research. The course's workload is expected to be completed in eight periods in the morning and ten periods at night, with a total duration of 2,850 hours and the course project implemented in 2012 is in line with CNE Resolution 2/2002.

The teaching degree in geography at UFMG has two mandatory curricular components related to cartographic knowledge: the subject of Cartography (60 hours), taught in the first period of the course, and the subject of Spatial Representation in Geography (60 hours), totaling 120 curricular hours for the specific approach to that knowledge.

Considering the general characteristics of the institutions involved, aspects related to cartographic knowledge worked throughout the courses are noteworthy because of the central point of this investigation. It is inferred about the possible role of this knowledge in expanding the intellectual repertoire related to spatial thinking.

Profile of survey participants

This study involved 289 students from the 1st and 4th years enrolled in the geography course at five different HEIs. It is worth noting the number of students per university from this universe, namely: UFG - 77; UFMG - 55; UERJ - 40; UFPel - 78; UFT - 39. In addition to answering the STAT questions, these students also filled out a socioeconomic questionnaire consisting of 11 questions, which aimed to know something more about these subjects, concerning their participation/experience at the university and their way of being admitted in the university: participation in a scholarship program, and their spatial mobility on the way home-university. From this questionnaire, it was possible to organize graphs and tables that sought to systematize these data. However, as much as this set of questions could offer us a lot of information, we consider it necessary to frame some data deemed more relevant to provide a first approximation to the readers through this article, which can be seen in figures 1 and 2, as follow.

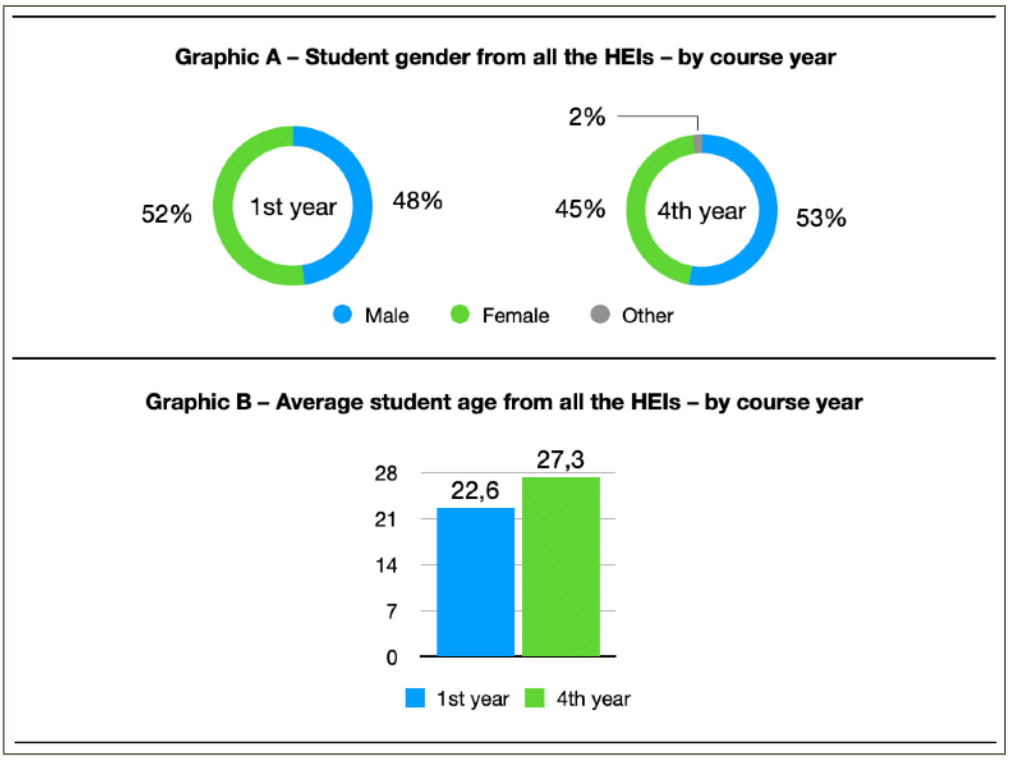


Figure 1: Gender and average age of students from HEIs participating in the STAT
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

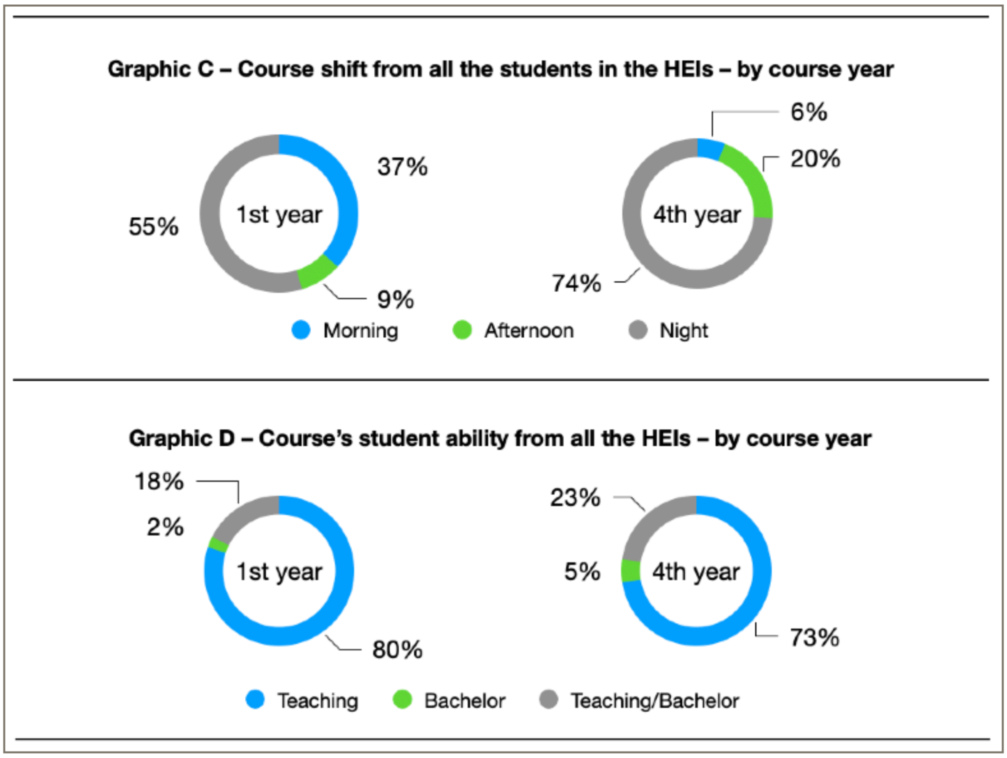


Figure 2: Shift and course qualification for students from HEIs participating in the STAT
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

The data from graphs A, B, C, and D, shown in figures 1 and 2, allow us to observe the gender diversity, the average age of students (22.6 years in the 1st year of the course and 27.3 years in the 4th year), the significant number of students who attend the evening course (55% in the 1st year and 74% in the 4th year) - a context associated with the fact that most of these students are workers - and the strong presence of undergraduate teaching students in this research. We recognize that these data allow us to know a little more about these students participating in this study. However, in the analysis of this information and others that were present in the socioeconomic questionnaire, we observed that it would not be possible to cross, at this time, the STAT responses with the question of gender, age, course shift, or qualification in the perspective of recognizing the specifics and particularities. The space limitations of this article have made impossible, for the time being, to deepen these very rich nexuses.

We understand that other analyses and investigations would be necessary to understand in greater depth whether the correct answers would have any relationship with some of the information present in the questionnaire. Because, as highlighted by Araújo, Oliveira, and Rossato (2017), the complexity that involves the research subject, his training and transformation process, are often not directly externalized in the answers presented in questions, interviews, or dialogues with the researcher. These may be initial clues for further interpretation, in which we will broaden the scope of our investigation. However, we consider it essential to share these previous data from HEI students so that the reader can have a brief understanding of who were the subjects who took part in the research and better understand the results of the questions included in the STAT, which will be presented below.

Global analysis of STAT responses

This section will analyze the set of answers given to the STAT questions by students from the five participating universities. We will evaluate both the performance in the test and, mainly, the performance verified in each of the eight spatial thinking competencies the test was designed to assess. This analysis will focus on comparing the aggregate performance of first-year students with the results of fourth-year students from the five courses that are part of the universe of this research. At this time, and due to the scope of this text, we will not proceed with the scrutiny of the differences verified between the institutions.

Another critical point to be highlighted is that, due to a typing error, question number 14 of the STAT was discarded from the tabulation performed to obtain the statistical data of the research, thus being out of the analysis developed here. Therefore, for statistical purposes, the test has 15 questions, corresponding to a 100% index for those students who answered the entire instrument correctly. In terms of competence assessment, the exclusion of question 14 does not have a very high impact since it is part of competence eight, also measured by three other questions, safeguarding the proper examination of the spatial thinking facet.

Thus, the global average of correct answers for the fifteen STAT questions by first-year students at the five universities was approximately 7.6 questions (50.54% of the questions answered correctly). The average of correct answers for the group of senior students was 8.65 questions (61.68%), a result about 14% higher than that obtained by the first-year students, as shown in Figure 3 below.

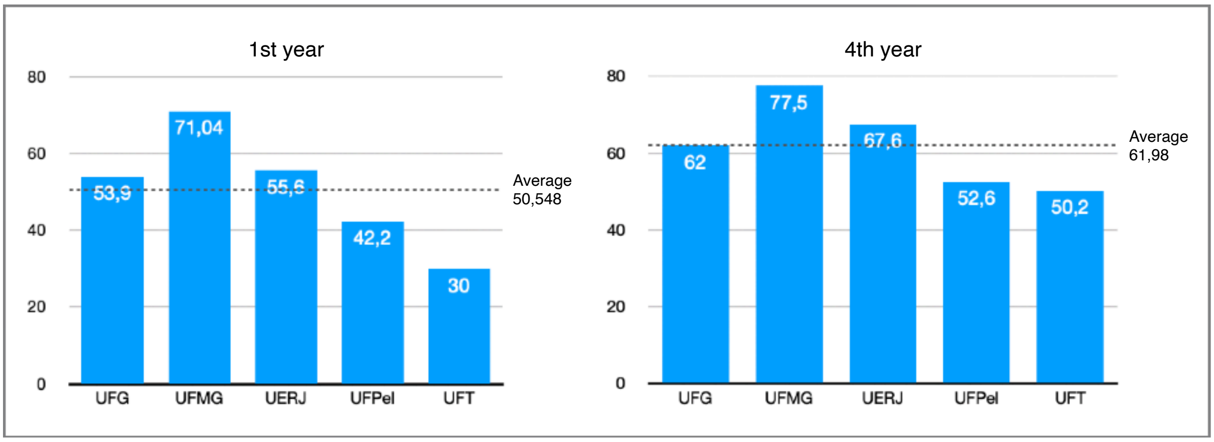


Figure 3: Percentage of correct answers for all STAT questions - by HEI - 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

Although very general and hiding regional/institutional differences, this first data is already worthy of our first reflection. The difference in performance between newcomers and veterans was much lower than the researchers' expectations. It was imagined that the four-year course would add substantially more proficiency to the skills in the field of spatial thinking strongly associated with cartography. Once it did not happen, even considering the eventual limitations and inaccuracies of the assessment instrument, it is opportune to deepen the analysis of curricular structures and pedagogical practices in geography courses all over the country, if we consider the sample of this research a valid one. This is a topic that we intend to highlight in the conclusions of this text.

The backbone of our analysis of the global results of the five universities will be structured around the examination of performances in each of the eight spatial thinking competencies assessed by STAT, according to the design defined by the test authors (LEE and BEDNARZ, 2012) and presented in Table 1 below.

Table 1: STAT - Types of questions and components of spatial thinking evaluated

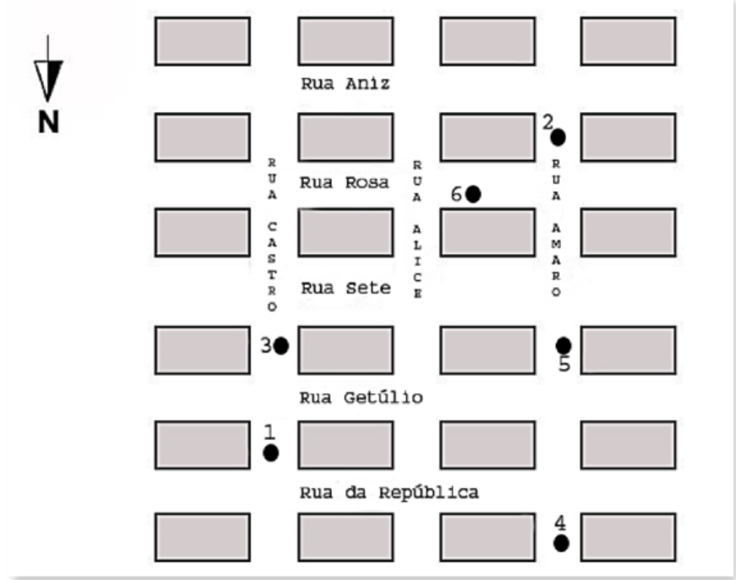
TYPE (item's number)	Item's description	Assessed components of spatial thinking
I (#1, #2)	In order to solve item #1 and #2, participants should visually navigate road maps using verbal information including participant's current location, directions to destination, street information, etc. (See Fig. 2)	Item 1# and #2 evaluate the trait of "comprehending orientation and direction (e.g., forward-backward; left-right; up-down; back-front; horizontal-vertical; north/south/east/west)" (Golledge 2002).
II (#3)	In order to solve item #3, participants should recognize map patterns and represent them in graphic form.	Item #3 assesses the trait of "discerning spatial patterns" (Gersmehl 2005) and "graphing a spatial transition" (Gersmehl 2005).
III (#4)	In order to solve item #4, participants should select an ideal location for a fictitious facility based on multiple pieces of spatial information such as land use, elevation, population density, etc.	The basic rationale behind item #4 is to assess the trait "comprehending overlay and dissolve" (Golledge 2002) and "inferring a spatial aura (influence)" (Gersmehl 2005).
IV (#5)	In order to solve item #5, participants should create a profile of topography along a proposed line on a contour map. In addition, the participants need to properly orient themselves in situ.	In solving item #5, participants deal with several cognitive traits including "recognizing spatial form (such as cross-sections to three-dimensional block diagrams or image)" (Golledge 2002), "being able to transform perceptions, representations and images from one dimension to another and the reverse" (Golledge 2002) and "graphing a spatial transition" (Gersmehl 2005).
V (#6, #7)	In order to solve item #6, participants should identify spatial correlations between sets of maps. Additionally, item #7 asks participants to display the identified spatial relationship in a graphic form. (See Fig. 2)	Item #6 and #7 evaluate the trait "comprehending spatial association (positive and negative)" (Golledge 2002), "making a spatial comparison" (Gersmehl 2005), and "assessing a spatial association" (Gersmehl 2005). Item #7 additionally assesses the trait of "graphing a spatial transition" (Gersmehl 2005).
VI (#8)	In order to solve item #8, participants need to mentally visualize a 3-D image based on 2-D information. (See Fig. 2)	Item #8 assesses the trait of "being able to transform perceptions, representations and images from one dimension to another and the reverse" (Golledge 2002).
VII (#9, #10, #11, #12)	In order to solve item #9, #10, #11, and #12, participants should visually verify a map overlay process and then select the appropriate map layers involved in the overlay. (See Fig. 2)	Item #9, #10, #11, and #12 correspond to the trait "overlaying and dissolving maps" (Golledge 2002).

VIII (#13, #14, #15, #16)	In order to solve item #13, #14, #15, and #16, participants should visually extract types of spatial data from verbally expressed spatial information. (See Fig. 2)	Item #13, #14, #15, and #16 measure the trait "comprehending integration of geographic features represented as points, networks, and regions" (Golledge 2002) and "comprehending spatial shapes and patterns" (Golledge 2002).

Source: Lee and Bednarz (2012, p.19-20)

Using table 1 as a reference, we can better understand the issues present in the STAT and the competencies that are assessed in each item of the instrument.

The first competency is assessed by the first two questions on the test and involves orienting oneself and setting directions using a representation of space (see Figure 4).



P.S.: Each rectangle represents a block in the city.

QUESTION 1: If you are located at point 1, walk north to the next corner and turn west, then after two blocks go south and walk two blocks, you will be near point:
(A) 2 (B) 3 (C) 4 (D) 5 (E) 6

QUESTION 2: If you are located at point 1, travel south just to the first corner and turn west, then walk one block and turn left, walk two blocks and turn west. Then, turn right at the first corner and follow four blocks. You will be close to point:
(A) 2 (B) 3 (C) 4 (D) 5 (E) 6

Figure 4: Image used to support STAT questions 1 and 2
Source: Lee and Bednarz (2012)

Questions 1 and 2 refer to a well-known and simple type of activity, applied even to elementary school students, but involving some operations that are a little more complex. In this competency 1, the aggregate percentage of correct answers, obtained from the average of correct answers for the two questions, was 54.46% for first-year students and 70.72% for veterans (forth-year), the latter performing approximately 30% higher (see Figure 5). This difference has brought us a particular surprise, as it was a little above then what we expected. We understood that the demand for the competence of orientation/direction of these two questions was so simple, and accessible even to Basic Education students, that we imagined that there would be a high and similar rate of correct answers among both beginners and senior students. We would not be surprised to see a result above 80% for both sets of students. The difference between newcomers and senior students was more than twice the difference between the two groups in the overall average score on the test (14% difference from the overall average score to 30% in this first competency). This may be associated with gaps arising from Elementary and High School, but we recognize that a more consistent response regarding this matter depends on further investigation.

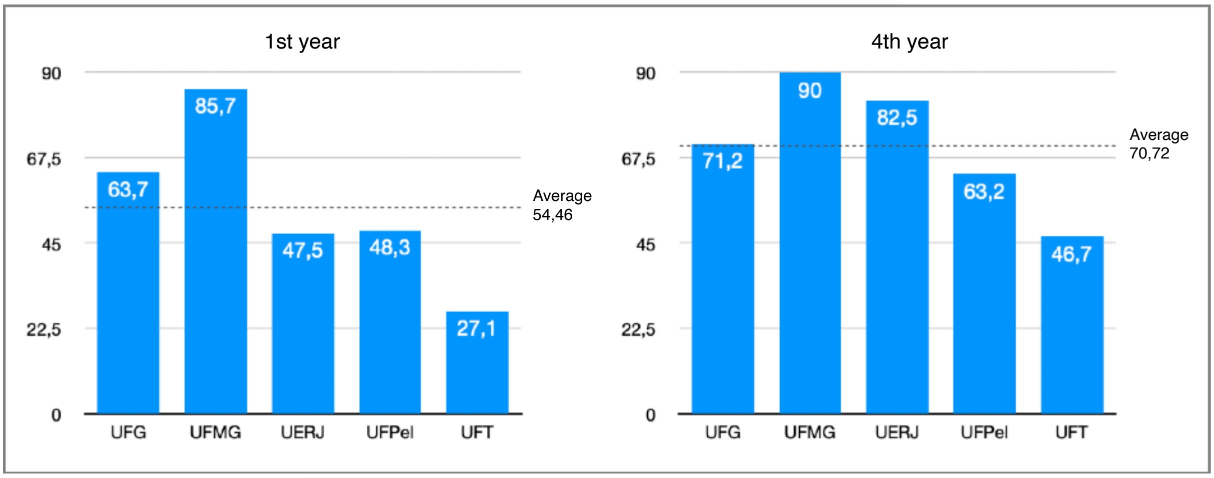
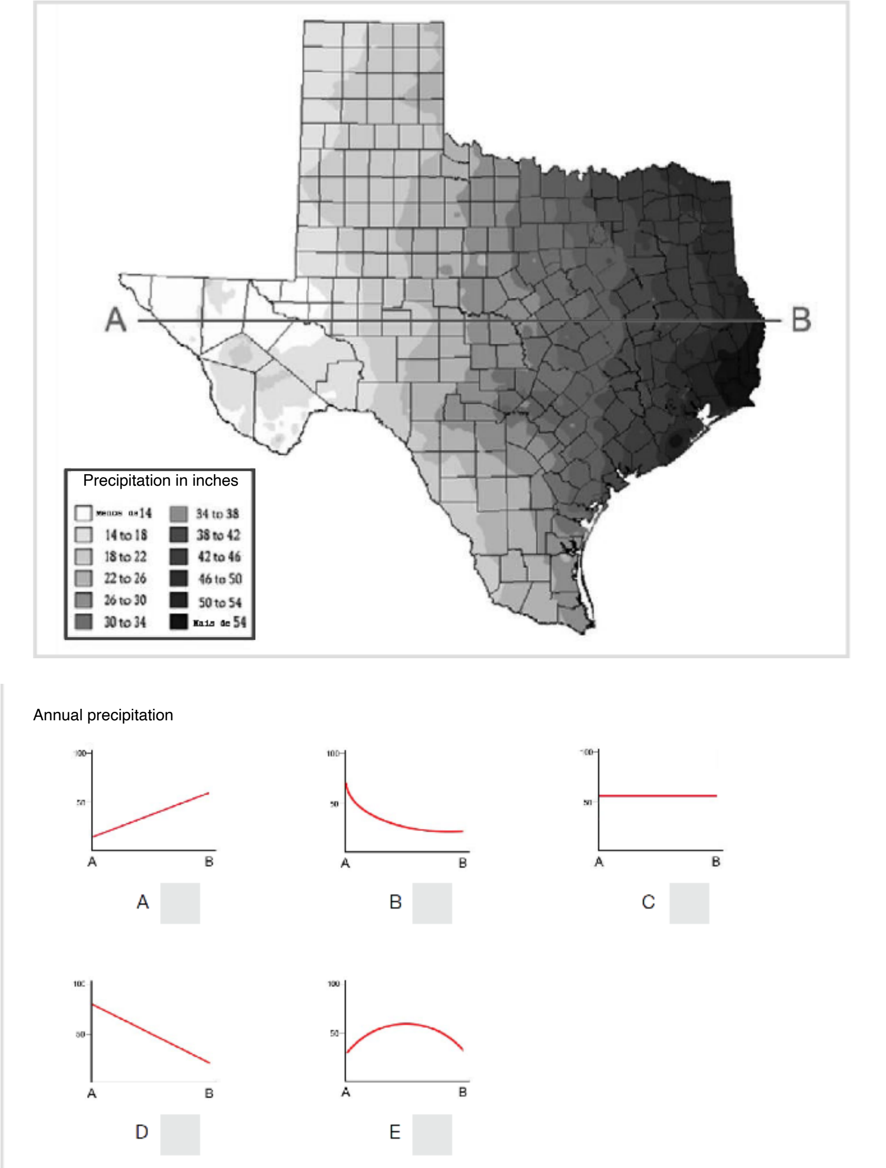


Figure 5: Percentage of correct answers for questions 1 and 2 (competence 1) of the STAT – by HEI 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

The difference between correct answers rate between the first and second questions, both components of this same competence, was relatively small, both in the 1st year (51.4% to 57.5%) and in the 4th year (67.4% to 74 .3%). We understand that this slight difference is reasonably coherent, considering that the difficulty levels of the two questions are similar.

Taking a general balance of this first competence, we evaluated that the average results of the 1st year students were below the expectations by the researchers, considering the relative simplicity of the charge and the familiarity of the students with this kind of questions, typical in Elementary School. In any case, the 30% difference in the performance of fourth-year students may suggest that, in this competence, the contribution of undergraduate courses was more relevant than other competencies that we will analyze below.

The second competence of spatial thinking is assessed by only one question, the number 3. It is, basically, the assessment of an integrated set of skills involving the reading of cartographic symbology (in this case, isolines), the ability to identify patterns, using this symbology, that express a spatial transition and represent them through another graphic form (Cartesian graph). See Figure 6 below.



QUESTION 3: The map above shows the annual amount of precipitation in the US state of Texas. The white color of the legend represents the areas with rainfall below 14 inches (about 350mm) per year, and the black color represents the areas above 54 inches (about 1400mm).

Figure 6: Map and graphics referring to question 3 of STAT
Source: Lee and Bednarz (2012)

The index of correct answers of first-year students in this Question 3/Competency 2 was a significant 77.94%, and, in the case of fourth-year students, it was 90.02% (see Figure 7). In our research, these are the highest average overall percentage of correct answers in the entire STAT. The domain of this competence was very high, signaling both a good domain of cartographic symbology and the translation of this information to the Cartesian format. However, in the name of transparency in our analysis, it is necessary to emphasize that the map was easy to read, and the transformation of cartographic information to the Cartesian graph was quite intuitive since there is an evident gradient of increased rainfall from West to East. We assess that this competence would be assessed more consistently if a second question demanded a higher degree of proficiency. Overall, we were delighted with the students' overall performance.

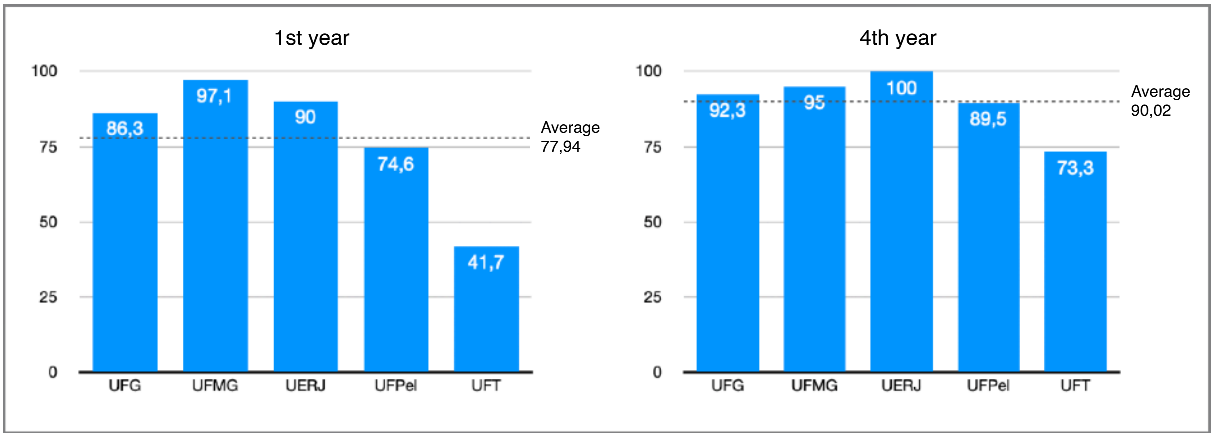


Figure 7: Percentage of correct answers for question 3 (competence 2) of the STAT - by HEI 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

The third competence was also measured using just one question, in this case, number 4 on the test. It essentially involves verifying the ability to mentally operate the overlay and merging of maps (GOLLEDGE, 2002) and, simultaneously, inferring the spatial aura (influence) of some spatial elements (GERSMEHL, 2008) to define an ideal location for a specific purpose. It is one of the most complex competencies of the test, and its assessment, through question 4, was based on a problem situation presented to the respondent (Figure 8).

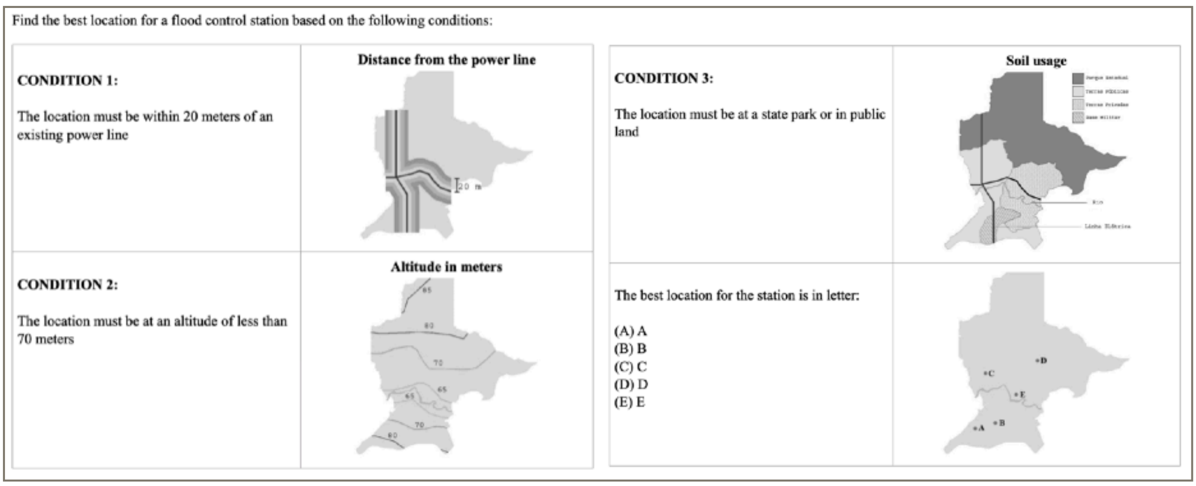


Figure 8: Maps referring to question 4 of the STAT
Source: Lee and Bednarz (2012)

In this Question 4/Competency 3, the first-year students from the five universities achieved an average of correct answers of 51.62%, and the fourth-year students reached 59.86%, a performance about 16% higher, as can be seen in Figure 9. We consider that the freshmen did relatively well in this competency because it involves a high spatial ability and abstraction level. The fourth year's hit rate have disappointed us because of our expectation that the course, in general, would have added quite a lot to the students' spatial thinking performance, linked to cartography and geography.

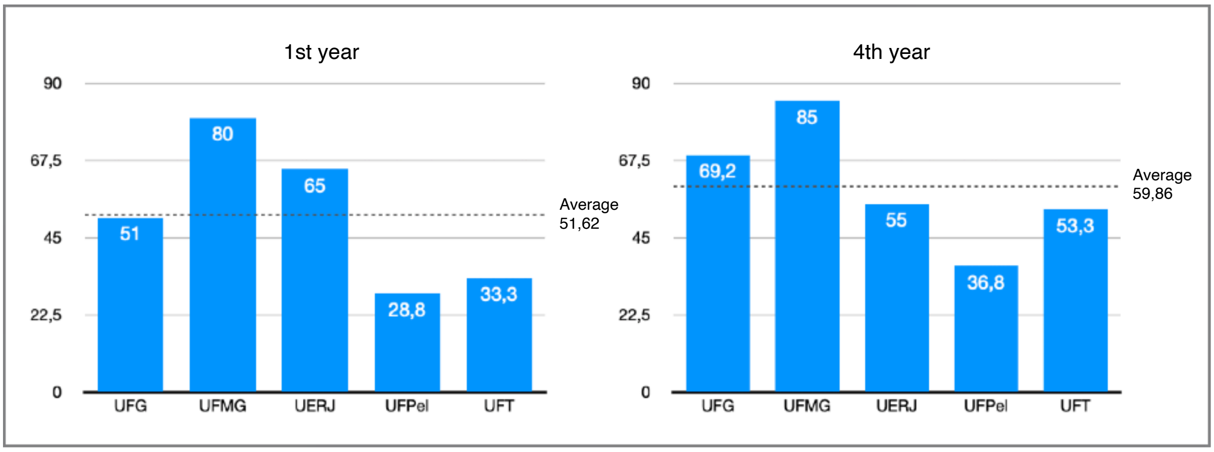


Figure 9 - Percentage of correct answers for question 4 (competence 3) of the STAT - by HEI 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

One of these aspects is that learning Geographic Information Systems, with the use of software such as ArcGIS and QGis, strongly involves the logic of working with layers of maps to merge them, according to the interests of the researcher/mapper. Therefore, this competence should have been well developed throughout the course. Where could the problem be? Could there be a low workload of courses that enable the use of this software in geography courses, particularly in the qualification of those preparing to be teachers? Is it the inadequacy of geoprocessing courses? Or could it be related to problems in the set of curricular disciplines, especially those concerning the undergraduate's cartographic training? These are questions that we asked ourselves and intend to investigate in the future, particularly by deepening the analysis of the differences in proficiency in the STAT, verified between the participating institutions, and their respective contexts of initial professional training.

The fourth competence is also verified through only one question, (number 5), shown in Figure 10.

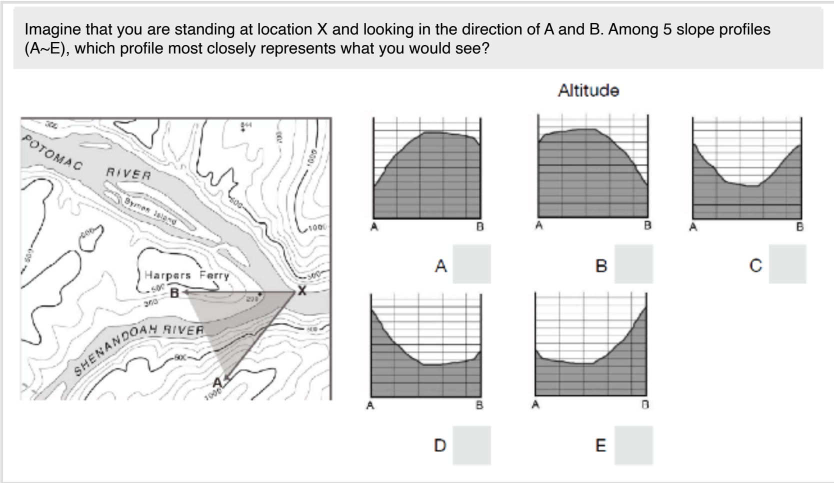


Figure 10: Map and graphics referring to question 5 of STAT
Source: Lee and Bednarz (2012)

According to the authors of STAT, who drew on the contributions of two central authors to the theme of spatial thinking, the set of cognitive operations mobilized in the solution of this issue involves "recognizing spatial forms (such as a cross-section of images or three-dimensional block diagrams)" (GOLLEDGE, 2002, apud LEE and BEDNARZ, 2012, p.19), "being able to transform perceptions, representations, and images from one dimension to another and in reverse" (id., p. 19) and "graphically representing a spatial transition" (GERSMEHL, 2008, apud LEE and BEDNARZ, 2012, p.19).

As can be seen, it is a competence associated with a relatively high level of proficiency in spatial thinking. From the results (see Figure 11, below), it was observed that the average of correct answers of first-year students was 48.42% and that of fourth-year students was 71.72%, with the latter result being almost 50% (48.12%) superior to their freshman colleagues. In this competence, we found what have seemed to us as being the most coherent scenario, according to researchers expectations, among all eight competencies of the evaluation instrument. The performance of newcomers was within our expectations (or even slightly above expectations) for the level of proficiency in spatial thinking and mastery of cartographic language demanded in the activity. On the other hand, the performance of graduates was reasonably high and significantly above that seen in beginners, which would signal a very positive effect of the training acquired in the course, concerning the development of spatial thinking.

Perhaps, as hypotheses, some factors contributing to this difference in performance are the more significant contact and familiarity with topographic maps throughout the geography course and the global development of spatial thinking associated with Cartography in the various disciplines of the course. What casts doubt on this second hypothesis is that this significant difference between newcomers and veterans was not repeated in the other seven skills of the test.

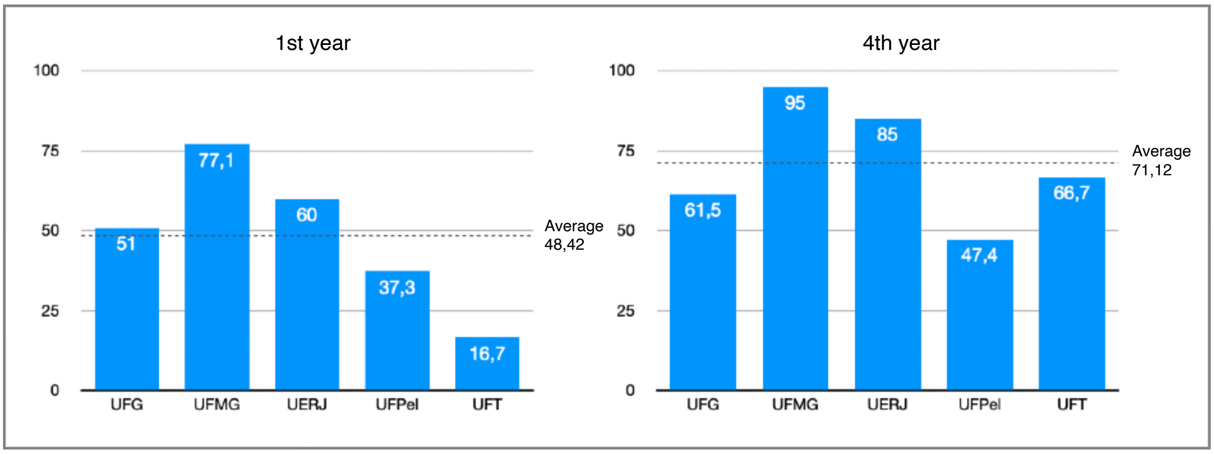


Figure 11: Percentage of correct answers for question 5 (competence 4) of the STAT - by HEI 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

STAT competency number 5 was examined using two test questions, numbers 6 and 7 (see Figures 12 and 14). In this competence, the authors of the instrument proceeded in what seems to be the most robust way to assess sets of cognitive processes of spatial thinking and which, as we suggest in this text, should have been adopted for the assessment of competence 2. They used two questions, with the second one being more complex than the first, enabling a more accurate assessment of the competence, based on the scrutiny of different levels of proficiency that were necessary to resolve the pair of questions.

Both activities 6 and 7 concern the ability to understand and assess a spatial association, both positive and negative (GOLLEDGE, 2002; GERSMEHL, 2008) and perform a spatial comparison (GERSMEHL, 2008). Question 7, in addition to this, adds the assessment of the ability to "graphically represent a spatial transition" (GERSMEHL, 2008, *apud* LEE and BEDNARZ, 2012, p.19).

Figure 12: Maps referring to question 6 of STAT
Source: Lee and Bednarz (2012)

The mental operation of spatial association demanded in question 6 (Figure 12) is relatively easy and intuitive, as the pattern of the reference map is easily associable with that of the map that corresponds to the correct answer. Probably, for this reason, both the first- and fourth-year students have performed very well, achieving the second highest average of correct answers of the entire test. For the first-year participants, the percentage was 66.6% and the senior students achieved 82.24%, a performance 23.5% higher than that obtained by their colleagues entering the course. This can be seen in Figure 13 below.

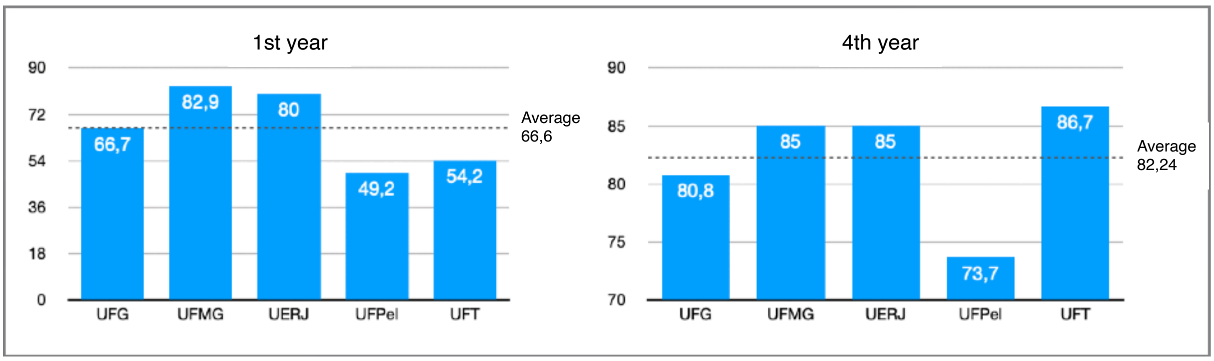


Figure 13: Percentage of correct answers for question 6 (competence 5) of the STAT - by HEI 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

In question number 7, the demand is much more complex (Figure 14). After reading and analyzing the two maps provided, the students should be able to identify a pattern of negative association between them. In areas with higher corn production, pork production is reduced and vice versa. The activity's statement asks the undergraduate to identify the Cartesian graph that expresses the spatial correlation between the amount of corn and the amount of pork produced in each city.

The following two maps show (A) Acres of corn production and (B) Value of hogs and pigs as percent of total market value of agricultural products sold. If you draw a graph showing the relationship between map (A) and (B), the graph will be

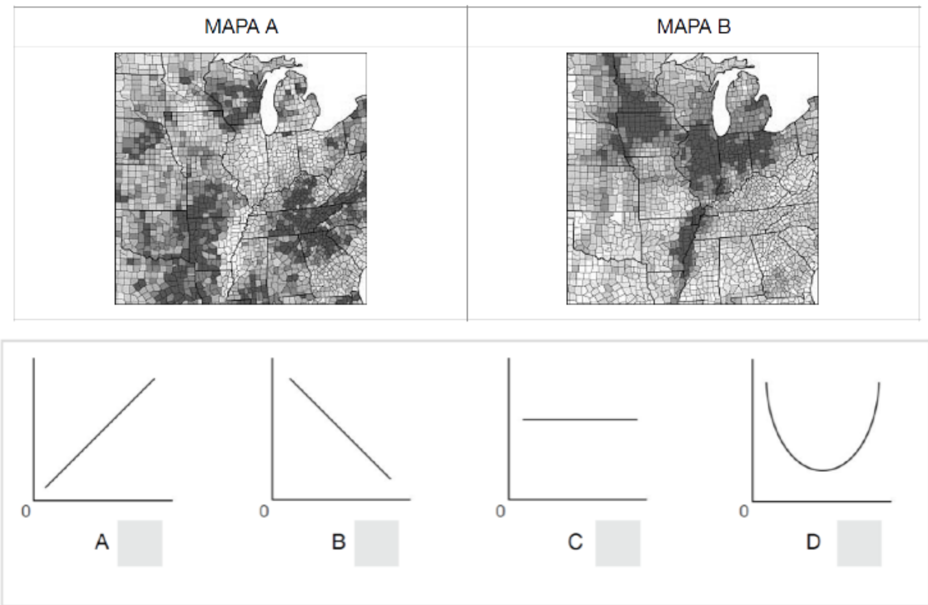


Figure 14: Maps referring to question 7 of STAT
Source: Lee and Bednarz (2012)

The much more complex cognitive operation required in question 7, undoubtedly explains the low percentages of correct answers for the two groups of undergraduates, 24.68% for first years and 17.34% for fourth years (see Figure 15 below). It is challenging to explain the low score of veterans compared to newcomers. The most likely hypothesis is the one we hoped not to be accurate. This competence in particular points towards the fact that there is a lot to do, when it comes to rethink undergraduate geography courses. Even if we consider that there are five different institutions and that it is expected that there are training inequalities between them, it is worrying to realize that, after four years studying, the veterans did not develop this competence of spatial thinking at a higher level of proficiency. It is worth remembering that the numbers presented here are the average of five institutions from four different Brazilian macro-regions. It is not, therefore, about the comparison between a group of freshmen with another of graduates, but the average of five groups of freshmen with the average of five groups of graduates, which rules out the possibility of being an isolated case. In addition, there is the fact that, even though the purpose of the present text is not to analyze regional and institutional differences, it is essential to point out that this decreasing performance among newcomers and graduates was registered in four of the five universities surveyed and that, when we look at the only exception, the performance of the graduates was slightly superior to that of the freshmen.

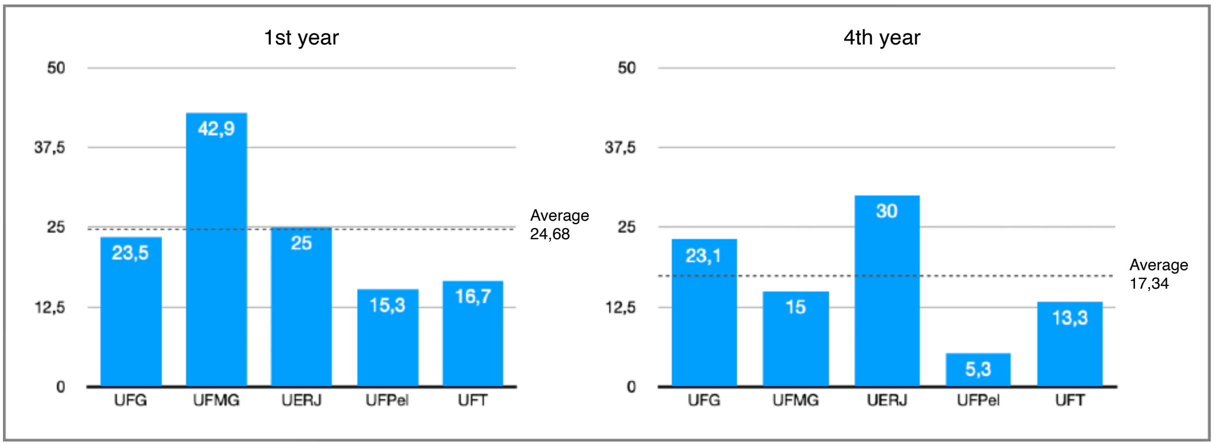


Figure 15: Percentage of correct answers for question 7 (competence 5) of the STAT - by HEI 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

It was crucial to disaggregate the two questions to scrutinize this fifth competence because they assess two considerably different proficiency levels, with very different results (although consistent) between the two of them. Aggregating the average results of the two questions would hide all those reflections that we carried out in the preceding paragraphs. The average percentage of correct answers for questions 6 and 7 was 45.62% for first-year students and 49.8% for fourth-year students. This kind of result would have little or nothing to contribute to the understanding of distinct performances that we have pointed out earlier and would not illuminate the underperformance of the graduates.

The sixth competency is the last one that is evaluated by only one question (Figure 16). It is, without a doubt, one of the most challenging questions on the test, requiring from the respondent some advanced skills in spatial thinking associated with space representations. Question 8/Competence 6 assesses the ability to transform representations and images from three-dimensional to two-dimensional representation and to reverse it.

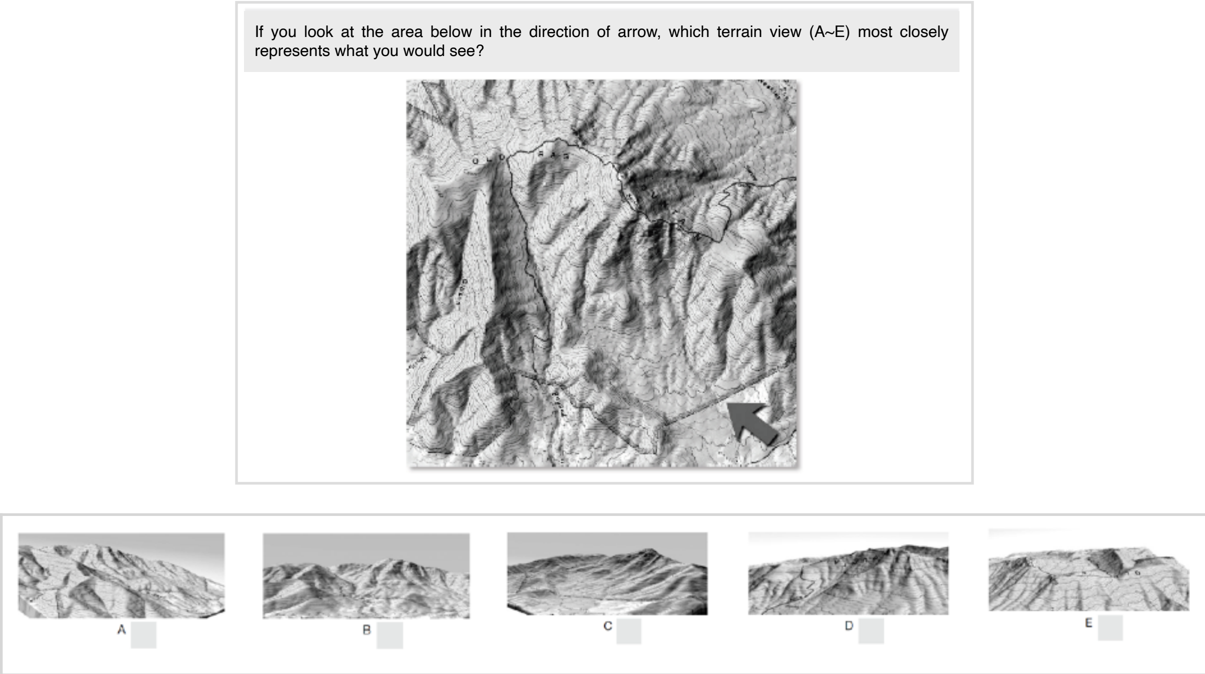


Figure 16: Maps referring to question 8 of STAT
Source: Lee and Bednarz (2012)

This very complex operation resulted in few correct answers for both groups, as shown in Figure 17. Only 28.86% of the first years answered this question correctly and 35.94% of the fourth years were able to do the same, a 24.5% higher performance. Here, once again, our concerns grow about undergraduate courses in geography, considering the objective of developing the spatial thinking of undergraduates. Limited performance of freshmen students, against a sophisticated competence in spatial thinking like this one, can be considered to be expected. Nevertheless, the poor performance of the graduates is something of great concern and deserves subsequent analytical developments to identify its causes and point out ways to overcome it.

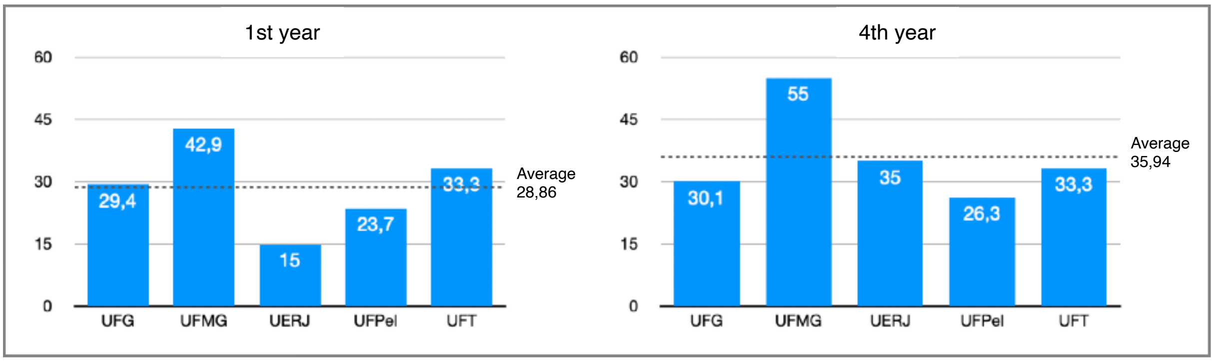


Figure 17: Percentage of correct answers for question 8 (competence 6) of the STAT - by HEI 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

The seventh and penultimate competence of spatial thinking assessed by the STAT involves four different questions, which, in principle, allows for a more accurate assessment. In this competence, due to a failure to apply the test for the fourth-year group at UFMG, we did not have access to the students' answers of that particular institution for questions 11 and 12. As a result, we decided to exclude data from the fourth-year students of the UFMG of our general accounting of the seventh competence. To calculate the competence average using only the answers to questions 9 and 10 would have distorted the results much more than the complete exclusion of the university in Minas Gerais.

The questions demand spatial visualization ability, known and measured by cognitive psychologists since the beginning of the 20th century. Questions similar to these ones can be seen as part of traditional tests called psychotechnical or even in newspapers' games and pastime sections. In STAT, these questions were inserted to verify the students' ability to "overlay and merge maps" (GOLLEDGE, 2002). Figure 18, inserted in the STAT as an example for respondents, gives an idea of the format.

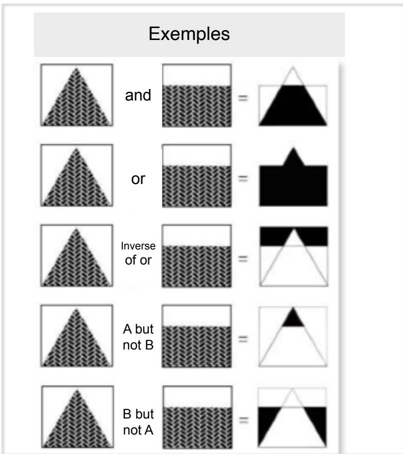


Figure 18: Graphic forms referring to STAT questions 9, 10, 11 and 12
Source: Lee and Bednarz (2012)

The four questions were well constructed to assess different levels of proficiency in this competence, as they have different levels of difficulty, and question 12, in particular, is very challenging. In fact, only 12 first-year undergraduates, out of a total of 189 evaluated, managed to get the four questions of this skill right (about 6.3% of the total). In the fourth year, among the 80 participants (excluding the UFMG students), only 9 (11.3%) achieved the same performance. The question with the lowest number of correct answers was number 12, with only 23.3% in the first year and 18.35% in the fourth year. The most straightforward question for the participants was number 10, with 63.58% correct answers for first-year students and 70.56% for veterans. The general average of correct answers for the four questions of this competence was 42.08% of the freshmen and 45.82% of the graduates. Figure 19 below presents these data.

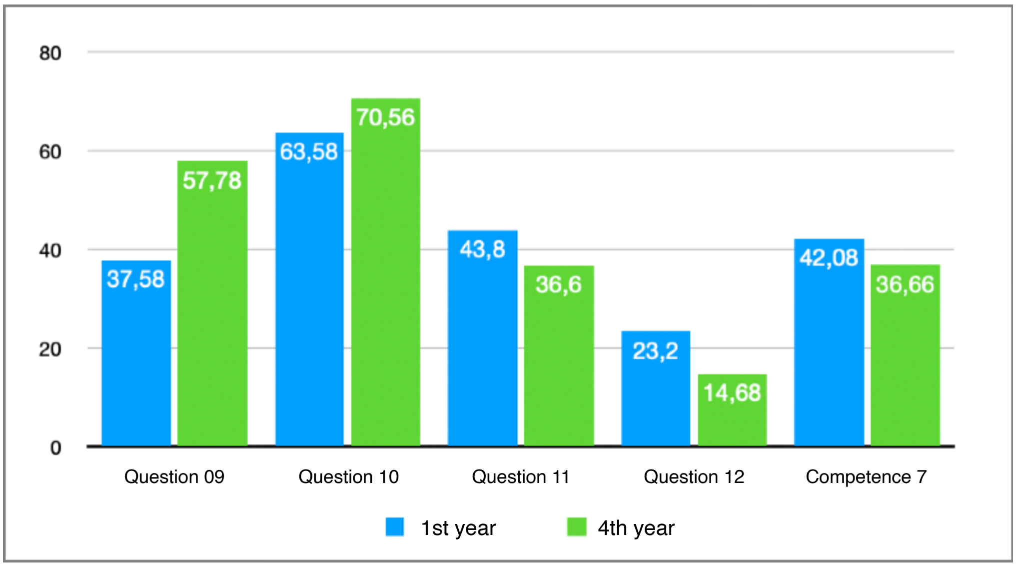


Figure 19: Percentage of correct answers for questions 9, 10, 11 and 12 (competence 7) of the STAT - all 1st and 4th year HEI
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

It is possible to verify that the difference in performance between the two groups is reduced and this, unfortunately, is one more result that points towards a less than desired development of students' spatial thinking linked to Cartography. However, it is essential to highlight that the absence of data from fourth-year students at UFMG certainly contributed to reducing the averages of these students, considering that the general performance of UFMG students in the STAT was relatively high.

In any case, competency 7 is admittedly complex, and, not by chance, the overall performance in this competency was the second lowest in the entire STAT for both groups. It was only above competency 6. Once again, considering that the purpose of constructing the questions to assess this competency involves verifying the ability to overlay and merge maps (in dialogue with competency 4), we are again concerned that the performance of the graduates was slightly superior to that obtained by the freshmen. Especially if we consider the learning with Geographic Information Systems throughout the course, in which this type of guidance is, in principle, frequent. Again, we return to the questions that need to be answered in the process of preparing geography undergraduate students and listed in the comments of competency 3.

Four questions would also evaluate the eighth and last competence, but due to the typographical error mentioned before, we excluded question 14 from this set. Thus, the evaluation was due to the number, still quite representative, of three questions, the 13, 15, and 16 (Figure 20). The main objective of the competency is to assess the ability to mentally associate geographic information with the proper use of the cartographic alphabet (points, lines, and areas/polygons) to represent them. Once again, we did not have access to the responses of fourth-year students at UFMG, and, for this reason, our averages correspond to those verified in the other four participating institutions.

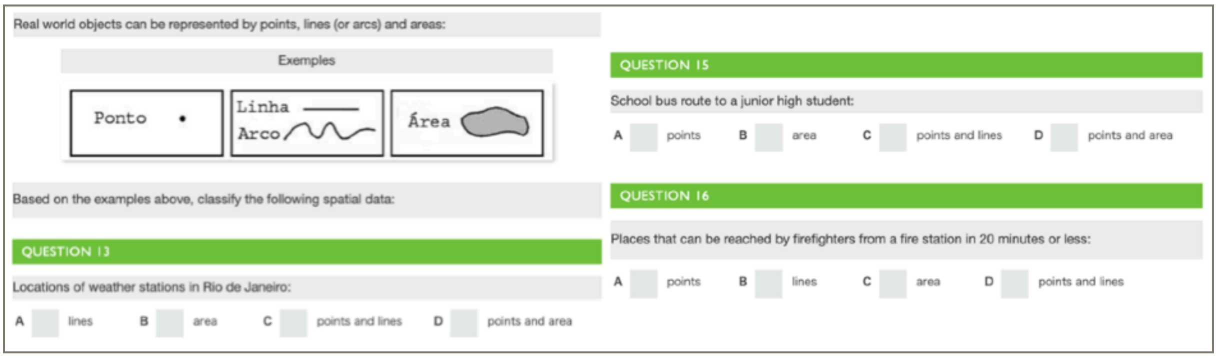


Figure 20: Cartographic alphabet referring to questions 13, 15 and 16 of the STAT
Source: Lee and Bednarz (2012)

We consider the competence to be one of the easiest in the STAT, and the percentages of correct answers for this competence were the highest among the eight that make up the instrument, in the case of the first year, and the second highest for the fourth year. Speaking about the latter, we recall that the absence of UFMG from the global average certainly reduced the index. If it were possible to compute the responses of the students from Minas Gerais, competence eight would also be the one with the highest percentage of correct answers for fourth-year students. The overall average of correct answers was 61.2% for first-year students and 58.33% for veterans (see Figure 21). For a comparison on more equivalent bases, the calculation of the general average for the first year without the participation of UFMG students would be 57.25%, slightly lower than for fourth-year students.

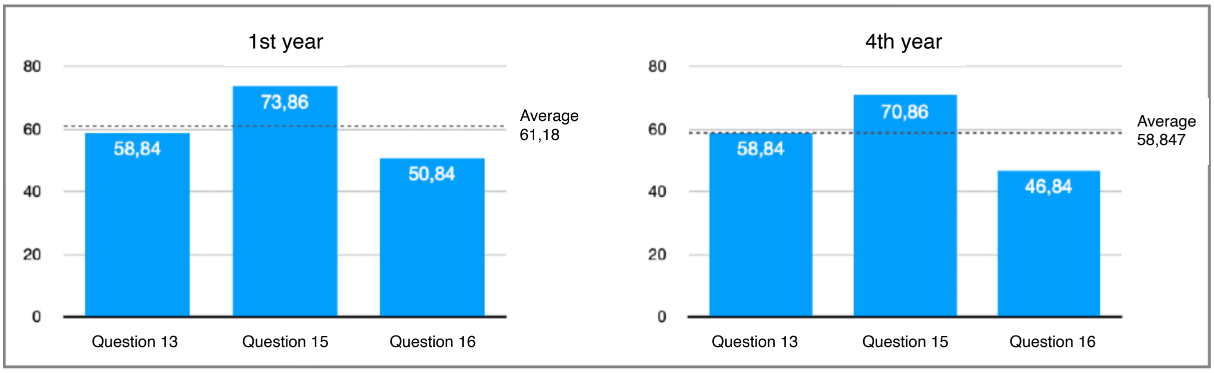


Figure 21: Percentage of correct answers for questions 13, 15 and 16 (competence 8) of the STAT - all HEI 1st and 4th years
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

As we have already stated, we believe that the average of graduates would be higher with UFMG grades, but even so, there are no grounds for projecting that the result of graduates would be much higher than that of first-year students, including what the comparative average data for the first year without the UFMG. Thus, the result surprised us negatively. Very high performance was expected, especially from veterans, for a reasonably simple competency. The result of first-year students can be considered as minimally satisfactory, although not desirable. However, the average performance of the final group was well below what we imagined. The reason for this is that such a basic task, restricted to the three essential elements of the cartographic alphabet and with straightforward problem situations (for example, what is the best way to represent the route of a school bus) should, in our opinion, have indexes of very high hits (above 80%).

Once again, we pose several questions about the initial training of undergraduates, especially, in this case, concerning training in the field of cartography. What would be missing in basic cartography disciplines so that trainees do not know how to correctly indicate the best representation of meteorological stations in Rio de Janeiro? The correct answer is (D) “Points and Area.” Even considering that the student could forget or disregard that the points alone would not deal with the problem presented since it is imperative to represent the municipality of Rio de Janeiro, there was no option with just the word “Points.” The other alternatives were: (A) Lines, (B) Area, (C) Points and Lines. Even by exclusion, it was expected that the graduating students would eliminate straight away the alternatives containing the representation by lines, staying between the option “Area” and “Points and Area.” Furthermore, given these two options, we do not understand any other way than to be sure that, to represent meteorological stations on a map at an adequate scale to encompass the city, the only way to represent the stations would be by points. Was it student’s lack of spatial thinking and basic cartographic knowledge that prevented them realizing that it would not be possible to represent the area of meteorological stations on this scale? Considering the possible cognitive paths, any possibility of a mental path that would not lead to correct answer seems to be a reason for much reflection and concern regarding geography teacher education. However, we know that this can only be answered with further investigative actions based on these results, which, incidentally, we see as one of the positive contributions of this research.

Because of these notes referring to the STAT questions, it is now appropriate to present a more systematic comparison of the growth in performance observed among students in the 1st and 4th years of all HEIs, concerning the competencies present in this test. Aiming this purpose, we have organized the graph in Figure 22, which highlights the increase in correct answers from freshmen students in comparison to seniors, making it possible to recognize, to a certain extent, the contribution of initial education to the understanding of knowledge related to spatial thinking.

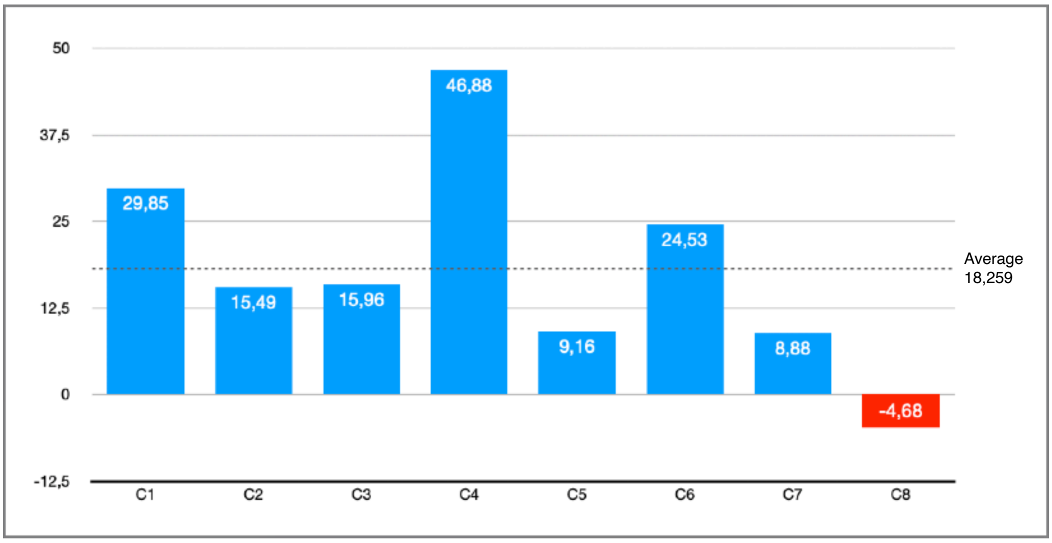


Figure 22: Comparative growth percentage of all STAT skills between the 1st and 4th grades - all HEIs
Source: Spatial Thinking Research Brazil, 2019. Org.: Authors, 2021.

The analysis of the graph in figure 22 allows us to make a synthesis of what we have punctuated throughout the text. Overall, the performance difference was below our expectations. We did not have a scientifically pre-defined numerical threshold of what could be considered a good level of growth in the performance of graduates compared to newcomers, even because we did not have knowledge of a study like ours, using the STAT, and that could serve as a parameter. However, the average of 18.25% seems to us to be relatively low, considering that the student in the first period practically did not have anu benefit of its just-initiated course and that graduates responded to the instrument after nearly four years of academic trajectory. There are some indications of undergraduate geography courses contribution to the construction of geographic thinking connected to spatial thinking, but unfortunately, they are somewhat punctual for us to make a positive global assessment. For us, these results are somewhat disappointing in terms of developing the proficiency of spatial thinking in the geographical field throughout undergraduate courses. This is because we understand that this cognitive sphere is crucial for geography professionals, whether they are bachelors or a teacher of the subject in elementary school (focus of our interest). In this sense, we agree with Metoyer, Bednarz, and Bednarz (2015, p. 22), who emphasizes that,

> Spatial thinking has always been a fundamental cognitive skill in geography. Space is a key organizing concept of our discipline. Furthermore, geographers use spatial thinking supported by spatial representations, such as maps, to: elaborate geographical questions; collect, organize and analyze geographic information; and explain and communicate geographic patterns and processes – critical practices for 21st-century skills development.

The idea exposed in the previous quote contributes to strengthening the importance of spatial thinking in the initial training process of geography students, more precisely in the curricula and programs that make up the courses that will train our future geographers. However, the data from this research allow us to infer how far we are from this desired goal in graduation courses.

Based on the data in Figure 22, it is possible to observe that the only competence in which there was a high advance in performance among first-year students and graduates occurred in competence 4, with an advance of almost 50%. As we have already stated, it was the most consistent performance, both due to the difference in performance between the two groups and the high percentage of correct answers by fourth-year students: 71.12% (difference of 46.88% more concerning the percentage of 48.42% correct answers of newcomers). The second case of significant difference among undergraduates occurred in competence one which, however, encompassed a type of activity that could be considered quite accessible even for elementary school students. In competency 6, the significant (but not very expressive) difference in performance, growing from the first to the fourth year (24.53%), contrasts with the low average rate of correct answers in the two groups in the case of veterans was only 35.94%.

In the other competences, it can be seen from the graph in Figure 22 that the difference between the two groups is small, standing in percentages close to the range between 9 and 15%, approximately. And it is important not forgetting the atypical performance in competency 8, with graduates scoring 4.68% lower than newcomers.

In short, the global analysis of the numbers indicates a very modest difference in performance between first and fourth-year undergraduate students in geography and a lower-than-expected performance in terms of percentage of correct answers for the two groups in competencies assessed through problem-solving situations that were considered as more straightforward.

Final considerations

We have reached the end of this article, which is nothing more than a first approach of our data referring to the spatial thinking of future geographers, understanding this cognitive modality as an essential part of geographical thinking or reasoning. The end here is, in fact, the beginning of future deeper analysis, concerning the intellectual operations demonstrated by students at the beginning and at the end of the geography undergraduate course.

We have started with a statistical approach, as Barbetta (2002) points out, quantitative surveys are generous in allowing us a broad view of a given issue. Quantitative surveys allow us to see and broaden the horizon, while qualitative surveys favor cutting and, subsequently, deepening the investigation. The STAT, as a diagnostic tool for spatial thinking linked to geography, was used consciously concerning the deficiencies that will always exist in this type of assessment, especially concerning something as complex as spatial intelligence. However, we understand that it has fulfilled its role of offering us clues for further investigation.

In this research, we have tried to see the horizon and, we believe, to have achieved our general goal. However, many points require further study, among which, we highlight the scrutiny of the differences observed between the institutions involved and the relationship between such differences and the results of the students. Another relevant aspect is linked to the understanding of specific performance on some questions, that have surprised us. For example, when students performed better than we expected or when the difference in performance between first-year students and veterans was much lower than the researchers' expectations. Why did this happen? Wouldn't geography courses being able to foster significant contributions to the spatial thinking competences of the students? If so, what problems can be identified in those courses regarding the training of future geographers, especially those of our most significant interest, the teaching undergraduates?

We do not have these answers and to obtain them, we will have to deepen the analyzes referring to the courses of the participating institutions, considering their curricular structures, programs, and pedagogical practices. Therefore, it is likely that we will start using qualitative methodologies.

Finally, we would like to point out that the presence of so many doubts demonstrate the potential of knowledge expansion contained in this research. One begins researching a set of issues and, if it is a well-done study, it ends with some assertions and a set of new question marks and, consequently, new investigations.

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