An Exploratory Assessment of Spatial Thinking among Geospatial Professionals in South Africa

Sanet Carow a,*, Serena Coetzee b, c and Peter Schmitz a
a Department of Geography University of South Africa,
sanetpc@unisa.ac.za, schimpmu@unisa.ac.za
b United Nations University - Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES), Germany, serenacoetzee@unu.edu
c Department of Geography, Geoinformatics and Meteorology, University of Pretoria, South Africa
* Corresponding author
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Abstract:

Spatial thinking is the cognitive skill of combining concepts of space, representation tools, and reasoning processes to solve complex spatial problems. Despite significant advances in geospatial technologies, individuals still lack this important skill, especially when working with maps and geospatial data. Spatial thinking abilities have been assessed for school learners and university students, but to our knowledge, not yet for those with work experience. A better understanding of the level of spatial thinking abilities in the geospatial industry can help us to understand whether experience and daily work with maps and geospatial data improve spatial thinking abilities. In this paper, we present the results of an exploratory study in which respondents from the geospatial industry of South Africa completed the spatial thinking ability test (STAT) developed by Lee and Bednarz (2012). Results indicate that gender, age, qualification level and discipline do not influence an individual's spatial thinking ability. However, work experience and the type of work people engage with on a daily basis impact a person's spatial thinking ability. Our results provide a baseline for further comparative studies, e.g., between the Global South and North, and also with other industries. In further research, the influence of other factors, e.g., dance, art and travel experience, on spatial thinking abilities should also be investigated. We encourage others to conduct similar studies so that the understanding of what develops spatial thinking abilities beyond a school and university education can be improved.

Keywords: spatial thinking ability, STAT, geospatial industry, South Africa

1. Introduction

Spatial thinking refers to the cognitive skills required to solve complex spatial problems (Cheng, 2016). An individual with well-developed spatial thinking skills can remember a map, plan a route, follow route directions, calculate and assess distances, detect spatial patterns, interpret three-dimensional topographic visualizations from different perspectives, contrast the characteristics of different locations and select an optimal location based on a set of requirements (Verma, 2015).

Overall, spatial thinking enables critical assessment and understanding of the spatial nature of spatial data, spatial analysis and spatial communication (Bearman et al., 2016).

Following the groundbreaking research of the National Research Council (2006) of the United States of America on spatial thinking, which recommended that an instrument was needed to measure a person's spatial thinking ability, Lee and Bednarz (2012) developed the spatial thinking ability test (STAT). Subsequently, researchers have applied the STAT to assess the spatial thinking abilities of school learners and university students (Ishikawa, 2013a; Tomaszewski et al., 2015; Verma, 2015; Fleming and Mitchell, 2017; Collins, 2018a; Flynn, 2018; Verma and Estaville, 2018; Carow, 2024).

The geospatial industry makes use of maps and geospatial data for understanding and solving problems. Geospatial technologies such as geographic information systems (GIS), remotely sensed geospatial data via satellites and drones, and Global Navigation Satellite System (GNSS) positioning play a significant role. Nevertheless, spatial thinking abilities, such as remembering a map, detecting spatial patterns, interpreting geospatial visualizations or selecting an optimal location, remain an essential part of what people do. GIS experts, geographers, GIS programmers, environmentalists, and remote sensing experts working in the geospatial industry require well-developed spatial thinking skills for solving complex spatial problems in their daily work. However, the spatial thinking abilities of people working in the geospatial industry, or any other industry for that matter, have not been assessed and reported to date. Understanding their abilities could shed light on training needs and whether experience and daily work with maps and geospatial data improve spatial thinking abilities.

This paper presents our exploratory research results on using the STAT developed by Lee and Bednarz (2023) to gauge the spatial thinking abilities of people working in the geospatial industry of South Africa. Additionally, the relationship between their abilities and their demographic background, experience, qualifications, knowledge, and skills was investigated. The next section describes the STAT and related research, followed by the methodology section that explains how the STAT was applied in this research. Next, the results are presented and discussed, followed by the conclusion.

2. The spatial thinking ability test

Spatial thinking is defined as a cognitive skill that combines three components: concepts of space, representation tools, and reasoning processes. A spatial thinker brings these three components into play to solve complex problems. A person's spatial thinking ability is their ability to process and apply spatial thinking to solve complex spatial problems (Cheng, 2016).

The STAT focuses on psychometric scales and intelligence and is the only spatial thinking test integrating geographical content knowledge. (Collins, 2018a). It consists of a pre- and post test that can be used in one of two ways. The pre- and post tests can be used to gauge the growth of a person's spatial thinking abilities, or either test can be used to assess a person's current spatial thinking ability. The STAT consists of 16 multiple-choice questions, categorized into different spatial thinking skills. Table 1 summarizes the eight spatial thinking skills and includes a description of each of the categories (Lee and Bednarz, 2012).

Table 1: Spatial thinking skill categories measured by the STAT

Question	Category
1,2	1: Comprehending direction and orientation
3	2: Comparison of a map and graphic information
4	3: Selecting the best location when given several spatial factors
5	4: Visualisation of a slope profile from a topographic map
6,7	5: Connecting spatially distributed phenomena
8	6: Visualisation of 3-D images from 2-D images
9,10,11,12	7: Overlaying and dissolving map layers
13,14,15, 16	8: Comprehending geographic features represented as points, lines or polygons

The STAT is not published, and permission must be obtained from the authors to use the STAT. Therefore, the questions in the STAT cannot be included in this article. However, Table 2 demonstrates two previously published questions as examples of questions asked in the STAT (Lee and Bednarz, 2012). The first question tests a person's ability to comprehend direction and orientation, while the second question tests their ability to visualize 3-D images from 2-D images.

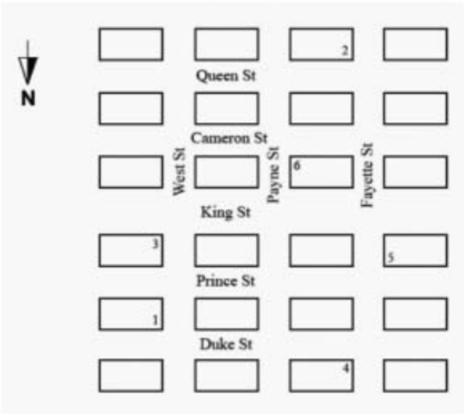
Table 2: Previously published questions from the STAT (Lee and Bednarz, 2012).

Not all individuals may perform well in all categories of the STAT; therefore, it should not be considered a test that a person will fail or pass (Lee and Bednarz, 2012). Instead, the test is an indication of the cognitive level at which a person can answer questions successfully and serves as an indication of components where spatial thinking should be developed (Verma and Estaville, 2018).

The STAT has been described as a “rigorously evaluated, conceptually robust and thoroughly validated spatial thinking assessment device” (Tomaszewski *et al*., p.41, 2015) and has been applied in various studies to assess the spatial thinking skills of school learners and university students (Ishikawa, 2013; Tomaszewski et al., 2015; Verma, 2015; Fleming and Mitchell, 2017; Flynn, 2018; Verma and Estaville, 2018; Carow, 2024).

Question 1:

DIRECTIONS: Answer questions on the basis of the street map below.

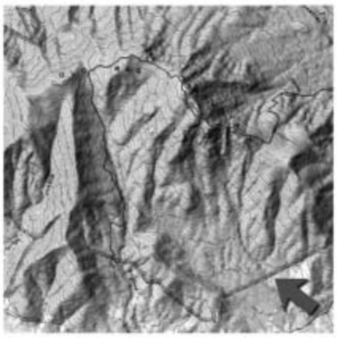


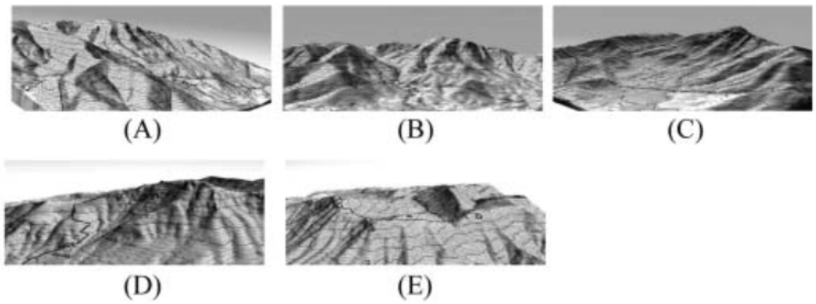
1. If you are located at point 1 and travel north one block, then turn west and travel three blocks, and then turn south and travel two blocks, you will be closest to point.

(A) 2
(B) 3
(C) 4
(D) 5
(E) 6

Question 2:

8. If you look at the area below in the direction of arrow, which terrain view (A~E) most closely represents what you would see?





At the school level, the pre- and post-tests of the STAT have been used to determine whether engagement with a giant travelling map improves the spatial thinking abilities of sixth-grade learners in the United States of America (USA) (Fleming and Mitchell, 2017) and to determine the differences in the spatial thinking abilities of urban and rural learners in Rwanda (Tomaszewski *et al*., 2015). The STAT was also used to assess the impact of digital technology *versus* paper on the acquisition of spatial thinking skills among learners and to determine methods to advance geospatial learning in K12 learners (Collins, 2018b). At the university level, the STAT has been used to determine the relationship between spatial thinking and spatial ability (Ishikawa, 2013b), to determine the spatial thinking abilities of undergraduate students (Verma, 2015), to establish the role of geography modules in improving geospatial thinking skills (Verma and Estaville, 2018) and to determine the spatial thinking skills of undergraduate students in the USA (Flynn, 2018). The latest research was conducted by Carow (2024) to determine the spatial thinking skills of undergraduate students at selected South African universities. The latter are compared to the results of the study reported in this paper.

Some researchers made slight changes to the STAT, most of which involved changing the metric units, the maps to reflect local context, and the wording of the questions. (Carow, 2024; B. Tomaszewski et al., 2015; Verma, 2015; Verma and Estaville, 2018). In addition, these researchers added questions to the STAT to provide context within the educational settings of school learners or university students.

Very few of the STAT studies to date have involved participants from the African continent, and only one focused on South Africa (Carow, 2024). None involved individuals employed in the geospatial industry.

3. Methodology

Two organisations were invited to participate in the study. The Geo-Information Society of South Africa (GISSA) represents the geo-information community of South Africa as a national, unified, representative body that promotes and protects the interests of its members (www.gissa.org.za). Amongst others, GISSA is registered as a voluntary organization with the South African Geomatics Council, the professional body for geospatial professionals, technologists and technicians (www.sagc.org.za), and represents its members' interests on the Council. The Society of South African Geographers (SSAG), on the other hand, aims to advance the research and educational activities of geographers in South Africa (www.ssag.org.za). Typically, GISSA and SSAG members are GIS experts, programmers, geographers, environmental scientists and managers, foresters and engineers who work with geospatial data in various ways. While they do not represent the entire geospatial industry, they are a core group for whom spatial thinking abilities are important. GISSA has 463 members, while SSAG has 489 members. A representative sample would comprise 45% of the members, i.e., 211 responses from GISSA and 216 from SSAG. After confirming their willingness to participate, ethics approval was obtained with the condition that participants had to be older than 18 years (REC-170616-051).

The questions in the STAT were adjusted with maps and place names to reflect the South African context, where applicable. Additionally, demographic information, such as age, gender, highest qualification, the discipline of the highest qualification, years of experience, and daily knowledge and skills used, was recorded. Respondents indicated in the organization in which they were a member. The purpose was not to compare the two organizations, but rather to calculate whether a representative sample was reached.

The online questionnaire was prepared using Microsoft Forms (Microsoft, 2025), and a link was sent to representatives of the respective organizations. The responses were returned to the researchers. All responses were anonymous so that an individual could not be identified from the response.

STAT responses were evaluated and differentiated into maximums, minimums and average scores per age, gender, highest qualification, the discipline of the highest qualification, years of experience, and daily knowledge and skills used. T-tests and one-way ANOVA tests were performed to determine whether significant differences exist between the average scores in the test and the results of the different spatial thinking categories of the STAT.

Although the link to the online questionnaire was sent to only the two organizations, anyone could pass it on, including to individuals not working in the geospatial industry. However, such individuals could be detected from their answers about the daily knowledge and skills applied in their workplace.

Other factors that could influence a person's spatial thinking abilities, such as dance, art and travel experiences, were not considered in this study (Verma, 2015). The influence these factors may have on the spatial thinking abilities of a person is complicated and falls outside the scope of this study. However, these factors cannot be ignored but can also not be controlled. The influence of such factors on spatial thinking ability has not yet been determined and has not been considered in the studies by other researchers.

4. Results and discussion

A total of 125 participants completed the online STAT. One of the participants indicated that he/she was born in 2006 or later, which means that they were 18 years or younger at the time of the survey. In conformance with our ethics approval (REC-170616-051), this response was deleted, bringing the total number of responses to 124. Participants completed the STAT in seven minutes to 23 hours and 37 minutes. Eight of the participants took longer than two hours to answer the questions. The timeframes for answering these questions suggest that the STAT was completed during working hours. These participants may have been distracted by other responsibilities and returned later to complete the STAT. If these outliers are ignored, the participants took an average of 35 minutes and 44 seconds to complete the STAT.

Most participants (78%) were GISSA members, while only two percent (2%) had SSAG membership, 14% were not affiliated with any organisation, six percent (6%) were members of another organisation, and two prevent (2%) were members of both GISSA and SSAG. We presented our study at one of the GISSA member meetings, inviting the audience to participate. In the case of SSAG, we had to rely on participants reading about the study on Facebook or X. This could explain the comparatively high response rate from GISSA members.

The 124 responses are not a representative sample of GISSA and SSAG. The data were therefore analysed with reference to the participants who completed the test. The results were only analysed by STAT category if there was a significant difference in the scores (based on the T-test or one-way ANOVA). Each data category — gender, age, discipline, qualification, and knowledge and skills — was tested for normality using the Kolmogorov-Smirnov Test of Normality before the t-test or ANOVA was applied. All the data sets were found to have a normal distribution with a p-value above 0.05.

4.1. Respondents' performance on the STAT

Generally, the performance on the STAT was high, with an average score of 11,6 out of 16 (73%). The scores varied from two (13%) to 16 (100%). Five participants obtained full marks, while 51 (41%) obtained a 13, 14 or 15 (81% - 94 %). Only 17 (13%) of the 124 respondents scored less than 50%. Participants scored the highest (96%) in category 2 (Comparison of the map and graphic information) and the lowest (55%) in category 7 (Overlaying and dissolving map layers). The average score for participants from the geospatial industry in South Africa was much higher than for that of a non-representative sample of South African university students, where the average score of participants studying at first-year, second-year and third-year levels was 43%, 46% and 52%, respectively (Carow, 2024).

The next sections present the STAT scores per gender, age, qualification and discipline, experience and skills and knowledge. The results are presented in two sections: first, variables without a significant influence on the spatial thinking abilities of the participants and then those with a significant influence.

4.2. Variables with no significant influence on the spatial thinking abilities of the respondents

Figure 1 illustrates the gender composition of the participants. Most participants (59%) were male, while 39 % were female. Two participants (2%) indicated their gender as 'other' or preferred not to divulge their gender. These participants were omitted from the data analysis regarding gender.

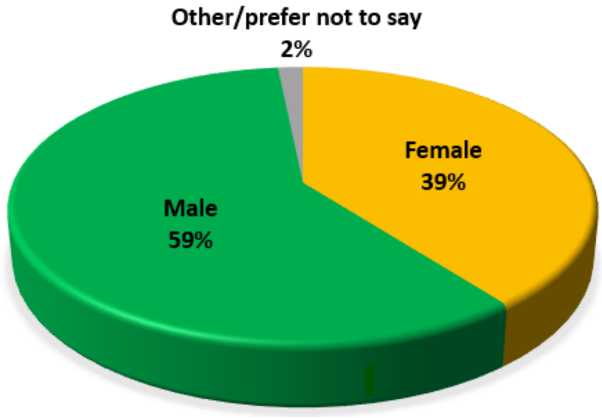


Figure 1: Gender composition of the participants

The average score of female participants was slightly higher (74%), compared to male participants (72%). (Refer to Figure 2). At least one participant from each gender scored a maximum of 100%. However, the lowest average score for male participants (13%) was much lower than that of the female participants (38%).

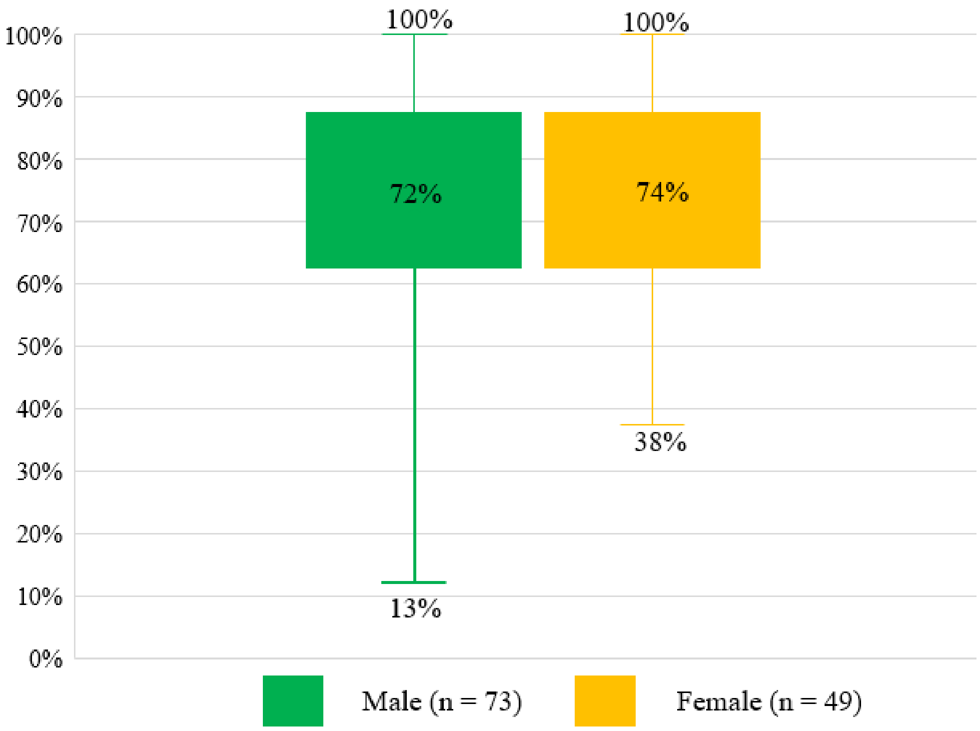


Figure 2: Average scores per gender

An independent t-test confirmed that there is no significant difference between the average scores for female (M=11.82, SD = 2.539) and male (M=11.59, SD = 3.018) participants. ($t(120) = 0.43398$, $p = .33254$). These results support the study by Metoyer and Bednarz (2017), Collins (2018a) and Carow (2024), which also found no significant differences in the spatial thinking abilities of male and female participants.

Hegarty (2018) and Carow (2024) found that male participants are better at a specific spatial thinking ability, namely mental rotation. However, our results for these categories – category 4 (Visualisation of a slope profile from a topographic map) and category 8 (Visualization of 3-D images from 2-D images) – showed no significant difference between the male and female participants. This can be attributed to the use of geospatial tools (GST) by the participants, reflecting the role of such tools in developing an individual's spatial thinking abilities (Shin *et al*., 2016).

The participants' ages ranged from 24 to 73. The results were categorised into six 10-year age categories, starting from 20-30 years and ending above 70 years of age (See Figure 3). Only one respondent was above 70, and was therefore included in the 61-70 years age category.

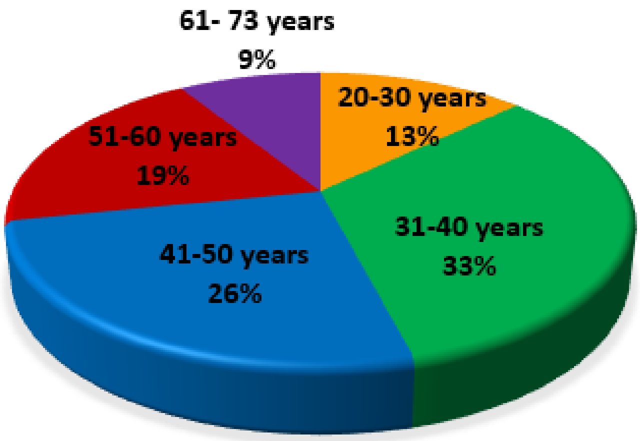


Figure 3: Ages of participants

Figure 4 summarizes the average STAT performance per age category. Participants in the 51-60 years age category obtained the highest average score (79%) followed by the 61-73 years age category (75%). The lowest minimum score was recorded for the 41-50 years age category (13%) The lowest scores for the 20-30 years, 31-40 years and 61-73 years age categories were all 31%. The 51-60 years age category scored the highest minimum score at 37%. Although the 51-60 years age category scored the highest average and the highest minimum score, this is the only age category in which nobody obtained a maximum of 100% in the STAT.

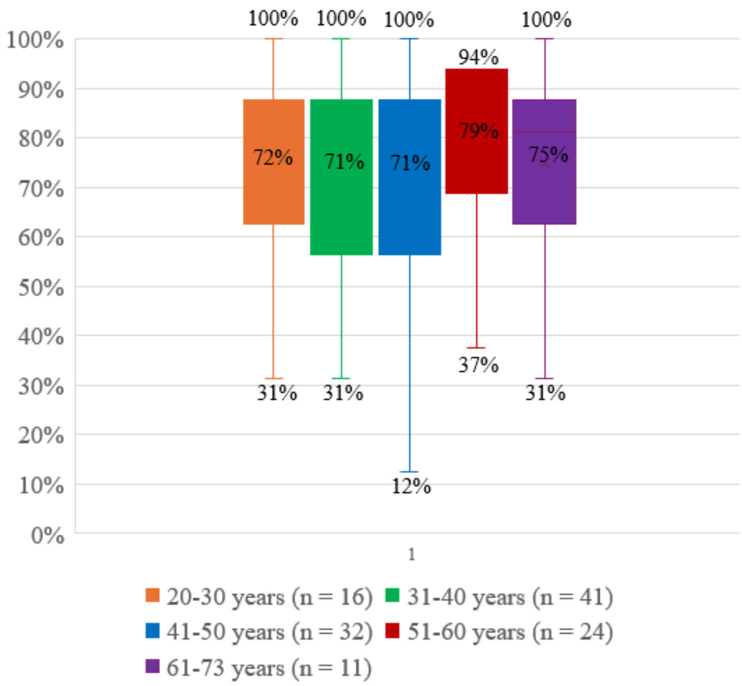


Figure 4: Average scores per age category

However, a one-way ANOVA revealed no significant difference in the average scores per age category (f-ratio value = 0.88437, p-value = .4756). Previous studies did not consider age as a potential influencing factor; therefore, our results cannot be compared to any previous findings.

Regarding participants' qualifications, seven percent (7%) chose the 'other' option or did not have a tertiary education. The number of participants in these categories was low. To ensure the anonymity of the participants, they were omitted from the analysis related to qualifications. A total of 33% of the participants hold an Honours degree (or a four-year degree or an equivalent credit-bearing certificate), followed by 23% with a Master's degree, 16% with a three-year diploma or equivalent credit-bearing certificate and 15% with a three -year degree or equivalent credit-bearing certificate. Ten per cent (10%) of the participants hold a PhD (See Figure 5).

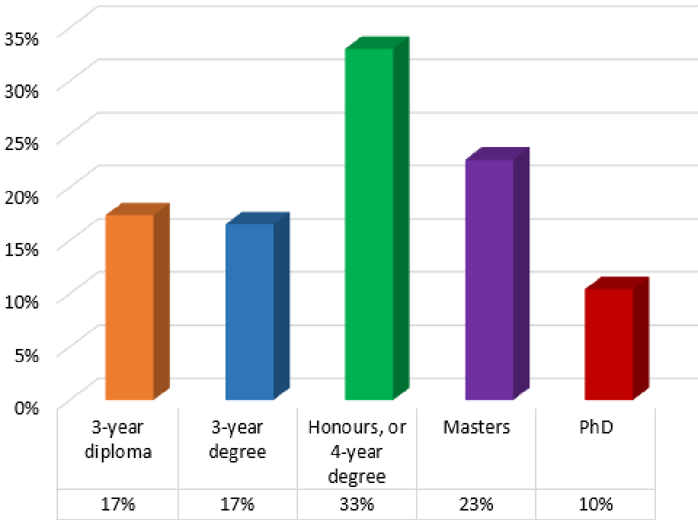


Figure 5: Qualifications of the participants.

Participants holding a PhD scored the highest average mark in the STAT (84%) followed by participants with a Master's degree (77%), Honours or four-year degree (73%) and participants with a three-year degree or equivalent diploma (69% each). The lowest minimum mark was scored by participants holding an Honours or four-year degree (13%) and the highest minimum score was recorded for participants with a PhD (69%). Participants holding a three-year or Honours degree scored the highest (100%), followed by the rest of the qualifications with maximum scores of 94%. (Refer to Figure 6)

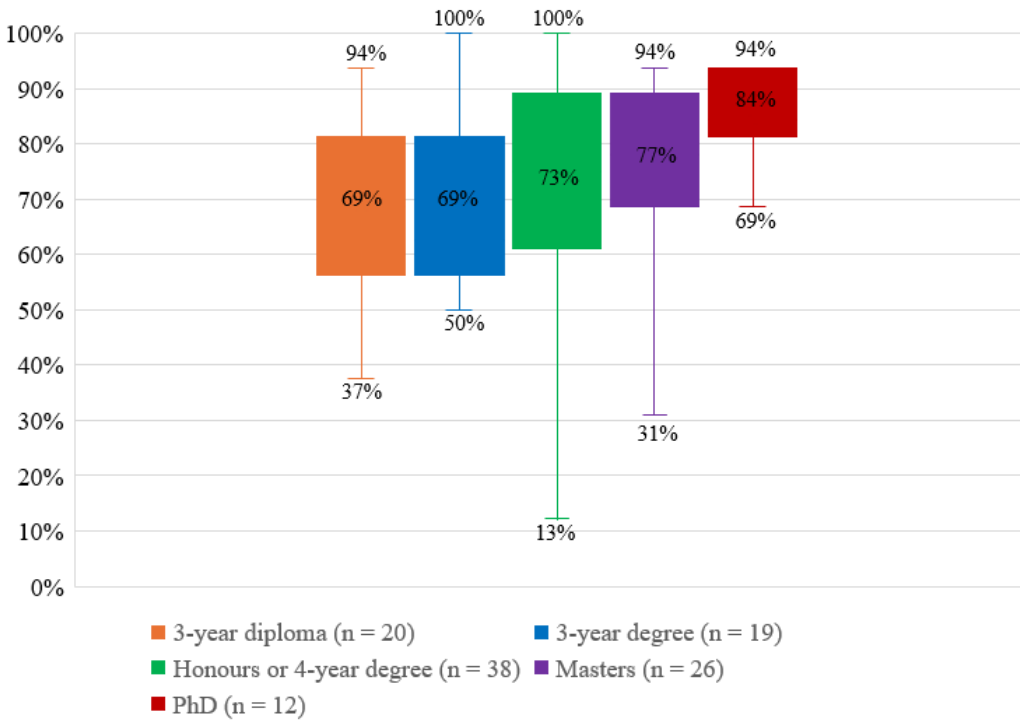


Figure 6: Average scores per qualification

Although there seems to be an increase in the spatial thinking abilities of participants from a three-year diploma to a PhD, a one-way ANOVA confirmed that the results are not significantly different (f-ratio = 2.15903, *p*-value = .078336).

Four of the participants do not have a tertiary qualification and could therefore not indicate a discipline in which the highest qualification was obtained. These participants were omitted from the analysis regarding the influence of disciplines on spatial thinking ability. The remaining responses were grouped into five categories: 1) Geoinformation and related disciplines, 2) Environmental and related disciplines, 3) Geomatics and related disciplines, 4) Computer Science and related disciplines and 5) Town Planning and related disciplines. Figure 7 illustrates the discipline in which the highest qualifications of the participants are held. All disciplines indicated by five participants or less were categorised into one category (Other). These include Statistics, Construction, Education, English and Law. This category was omitted from the rest of the analysis of the data as the number of participants per discipline was low.

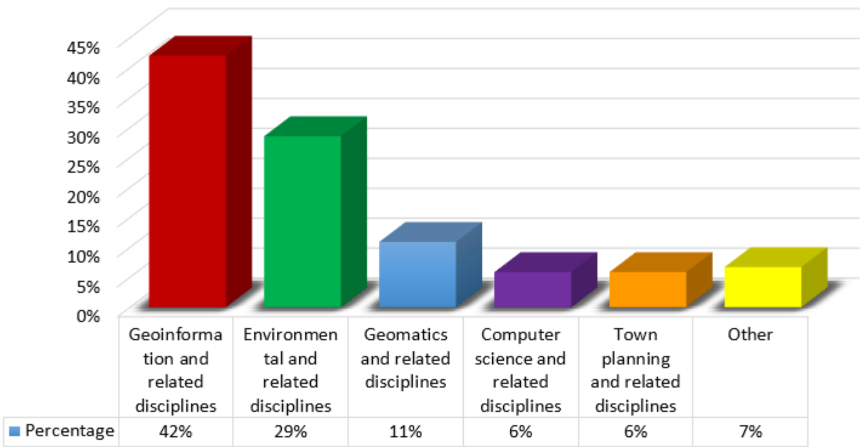


Figure 7: Disciplines of participants' qualifications

Not surprisingly, 42% of the participants hold a qualification in Geoinformation and related disciplines (including GIS, remote sensing and cartography), followed by 29% in Environmental and related disciplines (including Geography, Environmental Science, Botany and Climatology). Six per cent (6%) of the participants hold a qualification in Computer Science and related disciplines (including information systems) and Town Planning and related disciplines (including Town and Regional Planning and Urban Planning). This distribution reflects the purpose and typical membership of GISSA and SSAG.

Figure 8 summarises the average scores obtained per discipline of the highest qualifications of the participants. The highest average score was recorded for Geoinformation and related disciplines (78%), followed by Town Planning and related disciplines (77%). The lowest average score was recorded for Computer Science and related disciplines (63%). Participants holding a highest qualification in Computer Science or a related discipline also scored the lowest minimum (12%) and also the lowest maximum (88%). Participants holding a highest qualification in Geoinformation, an Environmental discipline and Geomatics or a related discipline scored a maximum of 100%.

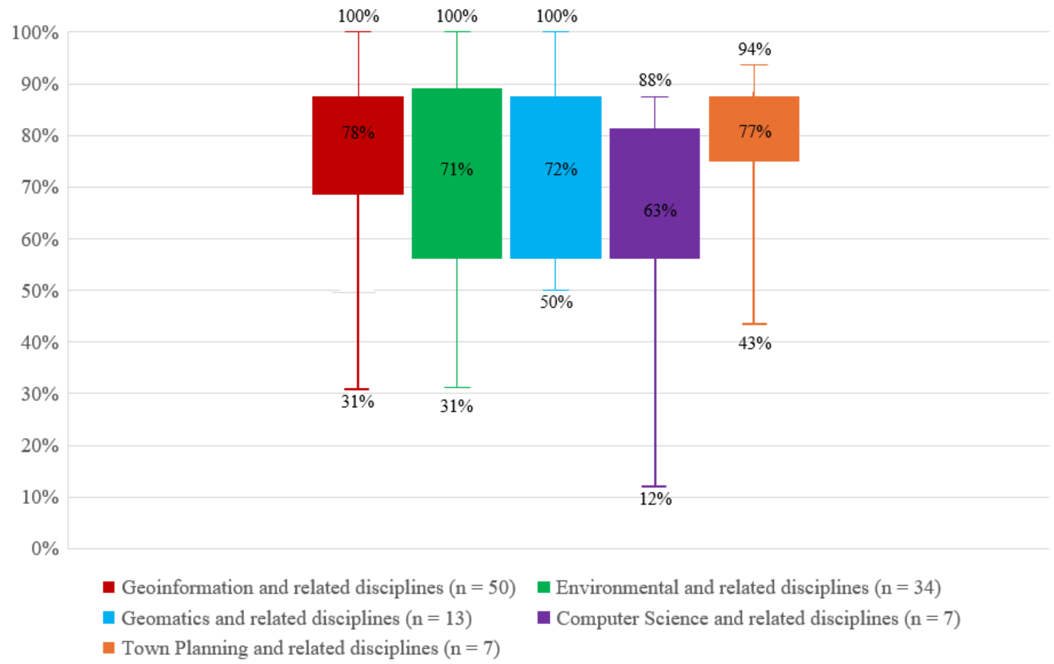


Figure 8: Average scores per discipline

However, a one-way ANOVA confirmed that there is no significant difference in the average scores of the different disciplines (*f*-ratio value=1.54914, *p*-value=.193365). Also in this case, the results of our study cannot be compared to other studies, as no studies to date have considered this variable.

The following section compares the variables with a significant influence on the spatial thinking abilities of respondents, using a one-way ANOVA first to determine whether there were significant differences in the average scores per category, and then the scores per category for further analysis.

4.3. Variables with a significant influence on the spatial thinking abilities of the respondents

The participants proved to be experienced in the industry. The number of years of experience varied from less than one year to 50 years. On average, the participants had 16 years of experience working in the geospatial industry.

Most participants (33%) had more than 20 years of experience in the geospatial industry of South Africa, followed by 20% with 10-14 years' experience. Participants with 15-19 years of experience constitute 18% of the respondents, and those with five to nine (5-9) years or five years and less constituted 15% each (Refer to Figure 9).

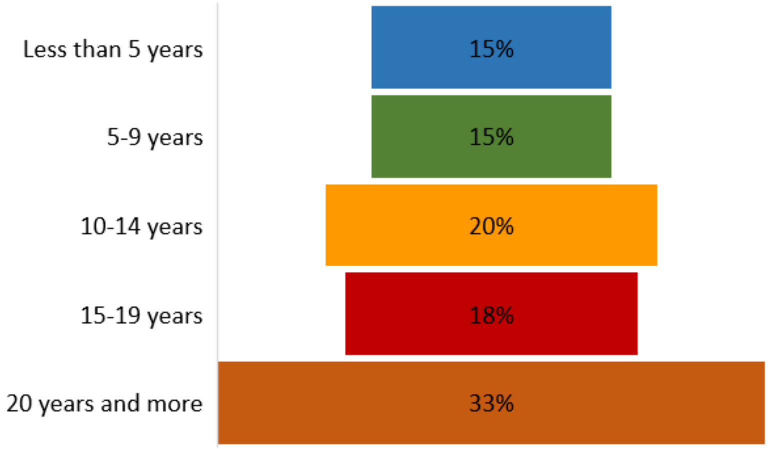


Figure 9: Work experience of the participants

Figure 10 summarizes the average scores obtained in the STAT, grouped by years of experience. Participants with less than five years of experience scored the lowest average in the STAT (66%). The average increases to 77% (5-9 years), 79% (10-14 years) and then decreases to 68% for each of the 15-19 years and 79 % for 20 years and more experience. The minimum scores are the lowest for the 15-19 years (13%) category and the highest for the 5-9 years (50%) category. The categories for 5-9 years, 10-14 years and 20 years and more scored a maximum of 100%. The other two categories, less than five years and 15-19 years of experience each scored a maximum of 94%. The reason for the decline in the average scores for the 15-19-year category cannot be explained by our results and should be investigated in further studies. A one-way ANOVA confirmed that there is a significant difference in the average scored in the STAT per years of experience (*f*-ratio = 3.30112, *p*-value = .013257).

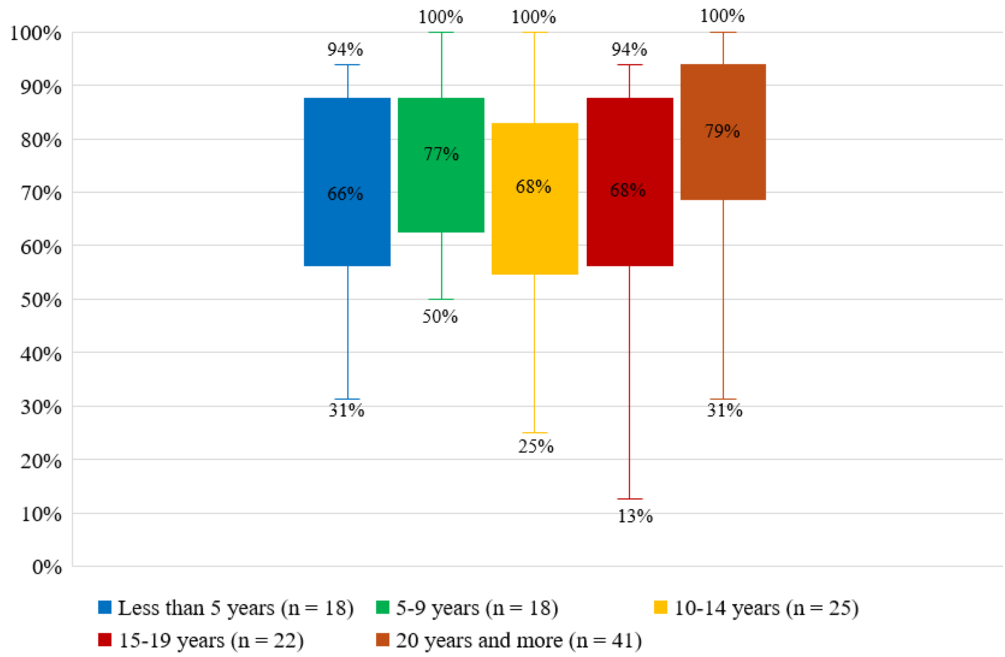
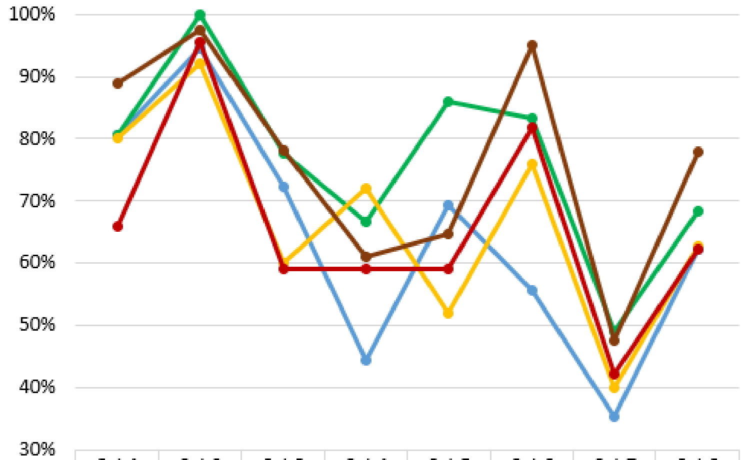


Figure 10: Average scores per years of experience

Figure 11 indicates the average score in the STAT per years of experience. There is a significant difference in the average scored for STAT category 5 (Connecting spatially distributed phenomena) and 6 (Visualisation of 3-D images from 2-D images). The result of the ANOVA test indicated that in the case of category 5 (*f*-ratio value=3.56808, *p*-value=.008722), there is a significant difference in the average scores of the participants. There were significant differences in the scores of the five to nine (5-9) year and 10-14-year categories and the five-to-nine (5-9 year and 15-19 years of experience. The participants with five to nine (5-9) years' experience scored an average of 86% in category 5, while the 10-14 years scored 52% and the 15-19 years, 59%. The reason why the average scores decrease with an increase in the years of experience is not known and should be explored in further research.

There is a significant difference in the average scores for category 6 (*f*-ratio=3.66401, *p*-value=.007502) between participants with 20 years and more experience when compared to participants with less than five (5) years' experience. Participants with 20 years and more experience (95%) outperformed those with less than five (5)years' experience (56%). From these results, it seems that participants with less than five (5) years' experience have challenges performing 3-D visualisation tasks. Educators should consider putting more emphasis on this in tertiary curricula.

It is also interesting to note that all the age categories performed poorly in category 7 (Overlaying and dissolving map layers). Carow (2024) found that students from selected South African universities also scored poorly in this category. The STAT is not a test one fails or passes but rather indicates which spatial thinking abilities are lacking. However, one would expect participants from the geospatial industry to have well-developed skills in the overlaying and dissolving map-layers category. Why this is not the case needs further attention.



	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Cat 6	Cat 7	Cat 8
Less than 5 years	81%	94%	72%	44%	69%	56%	35%	62%
5-9 years	81%	100%	78%	67%	86%	83%	49%	68%
10-14 years	80%	92%	60%	72%	52%	76%	40%	63%
15-19 years	66%	95%	59%	59%	59%	82%	42%	62%
20 years and more	89%	98%	78%	61%	65%	95%	48%	78%

Figure 11: Average scores in STAT categories per years' experience

The skills and knowledge that participants apply daily at their workplace are demonstrated in Figure 12. Most participants (29%) apply geospatial analytical methods, followed by cartography and visualisation (19%), geospatial data acquisition (15%) and geospatial data manipulation (14%). Only six percent (6%) of participants do programming and geospatial data design on a daily basis. The other skills applied by the participants (13%) include mathematics and skills that were not listed in the questionnaire. These small numbers were grouped into the 'Other' category and were omitted from the analysis of the data about skills and knowledge.

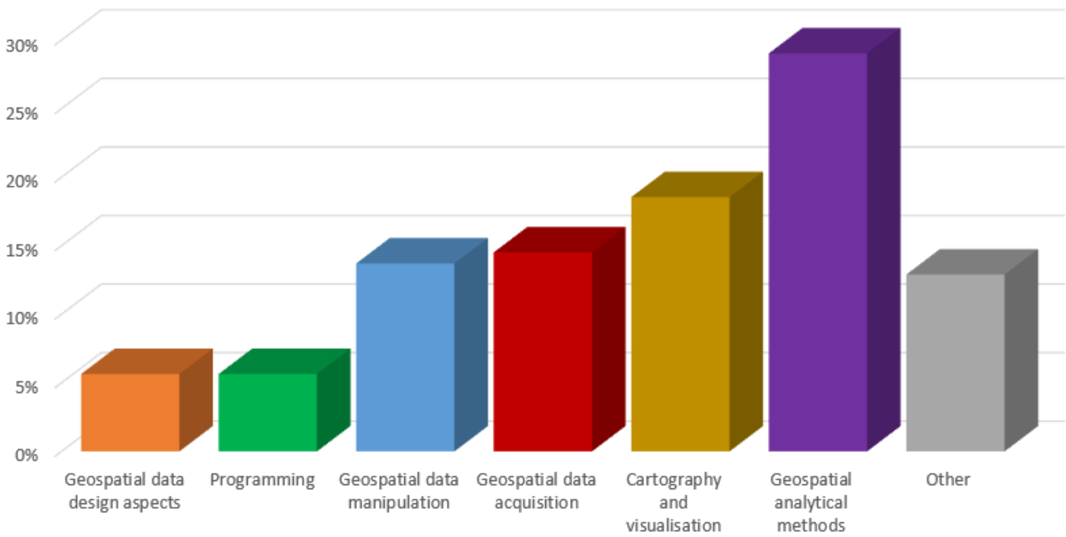


Figure 12: Skills and knowledge of the participants

Participants who are most often engaged in programming scored the highest average score in the test (82%),followed by participants who mainly use geospatial analytical methods (79%). Participants who most often work in cartography and visualisation, geospatial data acquisition and geospatial design aspects scored an average of 69%. Participants who manipulate geospatial data scored the lowest on average (64%). Participants who deal mostly with geospatial design aspects scored the highest minimum (56%), followed by those in programming (50%) and geospatial data acquisition (69%). Participants involved in cartography and visualisation scored the lowest minimum (13%) (Refer to Figure 13).

Interestingly, all categories scored a maximum of 100% in the STAT, except for participants who concentrate mainly on geospatial design (88%). A one-way ANOVA indicated that there is a significant difference in the mean scores in the STAT (F = 18.48261, p-value = 4.96825e-13). The spatial thinking abilities of the respondents are, therefore, influenced by the skills and knowledge they have. It is possible that a person's years of experience in the industry, combined with their knowledge and skills, may further influence their spatial thinking skills. However, a representative sample of participants from the geospatial industry will be needed to analyse this relationship further.

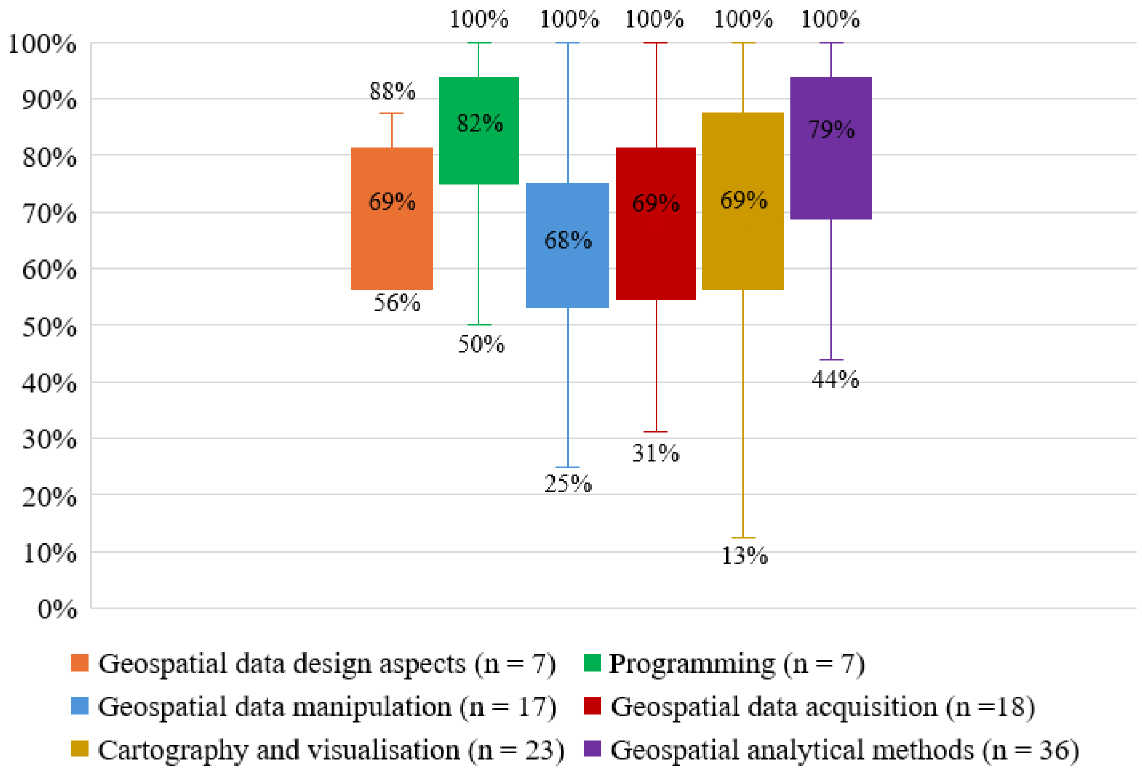


Figure 13: Average results per knowledge and skills

In relation to Figure 14, the one-way ANOVA indicated a significant difference in the average scores for category 2 ($F = 2.609389$, p-value $= .0290557$) and category 7 ($F = 3.956822$, p-value $= .00254614$). In category 2 (Comparison of the map and graphic information), significant differences were found in the average scores for participants who work mostly with geospatial data manipulation (82%): they scored lower than participants who mostly do cartography and visualisation (100%) and geospatial analytical methods (100%). This finding is not surprising; one could raise the question as to whether a person who is involved in applying geospatial data manipulation methods (e.g. data transformation) really needs skills in comparing maps and graphic information.

For category 7 (Overlaying and dissolving map layers), significant differences were found between the average scores for participants from two of the knowledge and skills categories. A significant difference was found between those who mostly do programming (62%) and geospatial data manipulation (30%), and a second significant difference between those who do geospatial data manipulation (30%) and geospatial analytical methods (54%). The participants who mostly do geospatial data manipulation (30%) scored much lower than participants who mostly do programming (62%) and geospatial analytical methods (54%). Furthermore, the one-way ANOVA did not find a significant difference between the scores for participants who mostly do programming and those who mostly do geospatial analytical methods. The questions in category 7 include the use of Boolean operators, often used in programming and overlays. It is, therefore, not surprising that these two groups of participants scored higher in tasks that involved skills they use on a daily basis.

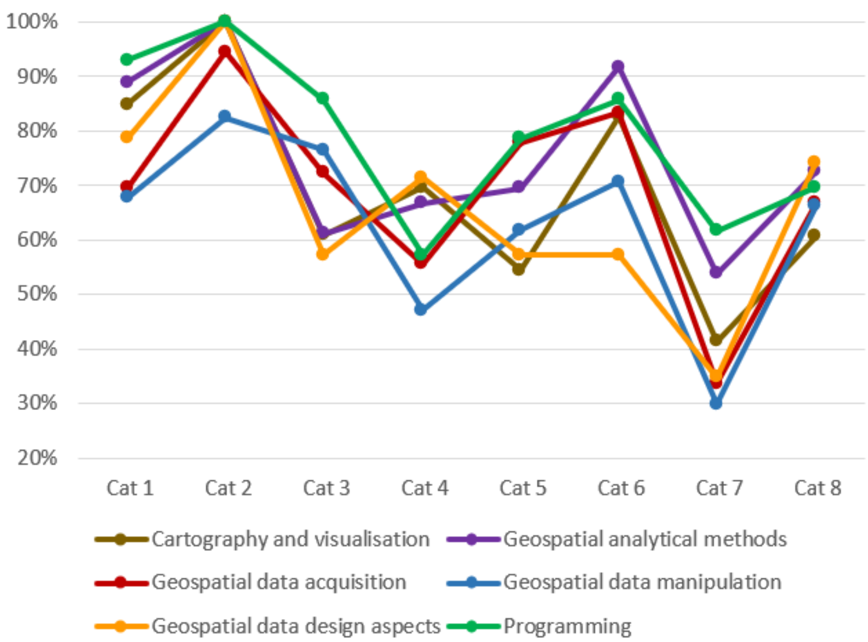


Figure 14: Average scores per the knowledge and skills category

5. Conclusion

This research used the STAT to gauge the spatial thinking abilities of respondents from the geospatial industry of South Africa. The responses are not representative of the two organisations invited to participate. Nevertheless, observations of interest to local and international audiences were made. In this study, no significant differences were observed in the spatial thinking abilities of different genders, age categories, qualification levels and disciplines. However, significant differences were reported in the case of years of experience and the knowledge and skills used by participants in their daily work. The STAT is not administered as a pass–fail assessment but is designed to indicate areas of variation in an individual's spatial thinking abilities. The performance in the STAT can be used to identify these gaps and to encourage individuals to attend specific courses that would develop these skills. However, care needs to be taken as not all participants would necessarily need all skills to complete their daily tasks. The STAT could also inform questions asked when interviewing job applicants.

This research lays the foundation for further comparative studies between participants from the Global South and North, and professionals in the spatial sciences not included in this study, e.g., civil engineers and architects. Further research using a representative sample from the industry will be needed to confirm the results of this study. If the results are confirmed, it would be interesting to know why there has been a decline in the spatial thinking abilities in the category 15-19 years of experience, which increases again with more years of experience, and if there is a relationship between years of experience and knowledge and skills. Also, the influence of other factors, e.g., dance, art and travel experience, on spatial thinking abilities needs to be investigated. To our knowledge, this is the first study on the spatial thinking abilities of people working in the geospatial industry, and, therefore, making a unique contribution in this regard. We encourage others to conduct similar studies so that insights into spatial thinking can be improved, and education and training can be designed accordingly.

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