Influence of Academic Variables on Geospatial Skills of Undergraduate Students: An Exploratory Study

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ABSTRACT

Spatial thinking and learning are essential components of geography education. The National Research Council’s 2006 report “Learning to Think Spatially” emphasized that people vary with respect to performance on spatial tasks. This pilot study at a large Texas university investigated geospatial thinking variances among undergraduate students based on academic experience of students. This exploratory study uses the Geospatial Thinking Survey (GTS), based on the Spatial Thinking Ability Test (STAT) endorsed by Association of American Geographers (2006) and published by Lee and Bednarz (2012), to assess the geospatial thinking differences of undergraduate students. The results show that academic major, academic classification, and exposure to academic geography influence comprehension of geospatial concepts, use of geospatial representation tools, and application of geospatial reasoning processes.

Key Words: geospatial thinking, geography, academic major, academic classification

INTRODUCTION

A groundbreaking National Research Council publication, Learning to Think Spatially, offered a new approach to spatial thinking (NRC 2006). The report defined spatial thinking as a constructive combination of concepts of space, tools of representation, and processes of reasoning, using space to structure problems, find answers, and express solutions. Spatial thinking is a cognitive ability to visualize and interpret location, position, distance, direction, relationships, movement, and change over space, in different situations and at different scales (Sinton et al. 2013). Geospatial knowledge helps us to make sense of chaotic and diversified environments (Golledge 2002). Geospatial thinking is important for significant everyday life exercises such as remembering a specific map, route planning, following directions to a lo-
cation, calculating distances and directions, determining spatial patterns among different features on land, visualizing 3-D topography from an alternative perspective, or choosing the best location based on given geographical criteria. The basic building block for spatial thinking is space, and the operations that humans can perform in space form its foundation. Geospatial thinking, focusing on the geography of human life spaces (spatial thinking at the level of Earth), is a subset of spatial thinking in general (Golledge, Marsh, and Battersby 2008b). Geospatial thinking is using Earth space or geographic space at different scales to frame problems, identify answers, and provide solutions employing geospatial concepts, representation tools, and reasoning processes.

The NRC argued that spatial thinking is universal, malleable, powerful, and pervasive in academic disciplines, the workplace, and everyday problem solving. Spatial thinking is a powerful problem-solving tool (NRC 2006). Geospatial thinking and reasoning are important because they are fundamental to many aspects of everyday life, to understanding the relations between different people and between people and environments, and to understanding differences in various cultures and regions of the world (Golledge, Marsh, and Battersby 2008b). Spatial and geospatial thinking also improve overall academic performance and increase student participation in mathematics and science careers (Newcombe 2010; Uttal et al. 2013). Spatial and geospatial training prepares students for many careers, including logistics, transportation, real estate, agriculture, natural resources, and military operations. Ignoring spatial and geospatial thinking education directly implies neglecting one of the key ways with which human brain comprehends and organizes information (Gersmehl 2012). The NRC (2006) identified its predominant goal as training students to adopt and practice spatial thinking habitually.

The NRC report highlighted that spatial thinking can and should be taught at all levels in the educational system because of its importance in research, academics, workplace, and everyday life situations (NRC 2006). Reports have claimed that spatial and geospatial thinking can be inculcated by education, training, and practice, such as lessons in geography (Liben 2006; NRC 2006). Scholars have emphasized that geography as a subject relies on spatial concepts as its foundation and thus provides exceptional spatial and geospatial training to students. However, many other disciplines such as physics, art, dance, mathematics, and computer science also focus on spatial concepts. It is important to confirm with empirical research, and not just theoretical claims, that geography is actually better than other disciplines in improving spatial and geospatial thinking of students. Curriculum and teaching modules should then be designed specifically to improve geospatial thinking of students coming from different backgrounds. Liben (2006) and Newcombe (2010) observed that people vary with respect to performance on spatial thinking tasks. Addressing the issue of group differences in geospatial thinking will assist in outlining different learning paths and ways for different groups of students (Anthamatten 2010; Gersmehl 2012), such as those belonging to different ethnic groups with varying levels of geospatial thinking.

PURPOSE

Significant differences occur among people as to how, how quickly, and how well they understand and do something. Like different levels of performance exist in spatial thinking as a function of age, sex, and experience (NRC 2006), students from various academic majors and classifications (year in college) may also demonstrate differences in approaching and assimilating spatial thinking. “These variations might reflect different progress rates through developmental spatial achievements, different developmental end points, differential access to non-spatial component skills that are needed for spatial processing (e.g., working memory), or differential success in activating competencies.
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in a given test environment (e.g. as a consequence of test anxiety)” (Liben 2006, 208). Investigating the nature of group differences, based on variables such as academic major, academic classification, or academic experience in geography, can lead to a better understanding of the comprehension and use of spatial thinking. Classroom tools, curricula, and assessments could be designed on the basis of any such explored differences to instill geospatial thinking in students (Anthamatten 2010; Gersmehl 2012).

Scholars in geography and other disciplines have researched extensively about sex and age differences in spatial thinking. Few studies have addressed the issue from a perspective of academic majors, academic classifications, and background in geography of university undergraduates to discern differences in geospatial thinking.

The purpose of this study is to investigate group differences in geospatial thinking of undergraduate students at a large Texas university. The primary research question is: Do academic major, academic classification, school geography academic experience, and/or college geography academic experience influence the geospatial thinking of undergraduate students? I examine whether there is a statistically significant difference in geospatial thinking ability among students with different academic majors, at different stages in their academic career, and with differing degrees of exposure to academic geography.

LITERATURE REVIEW

Scholars in geography and other disciplines have studied group differences in spatial thinking but have mostly focused on sex, age, and K-12 school grade-level (Allen 1974; Gilmartin and Patton 1984; Cochrane and Wheatley 1988; Lawton 1994; Voyer, Voyer, and Bryden 1995; Henrie et al. 1997; Albert and Golledge 1999; LeVasseur 1999; Montello et al. 1999; Hardwick et al. 2000; Lee 2005; Levine et al. 2005; Battersby, Golledge, and Marsh 2006; Marsh, Golledge, and Battersby 2007; Golledge, Marsh, and Battersby 2008a; Huynh and Sharpe 2009, 2013; Lee and Bednarz 2012). Other variables, such as academic major, academic classification, and academic background in geography, should also be investigated as well for differences regarding geospatial thinking abilities. Investigating such group differences is important for effective interventions, for example, in the form of properly tailored map and GIS exercises in geography classrooms. Students in several academic majors and workplaces may have to deal with spatial and geospatial thinking but they may not be equally competent if their geospatial thinking skills are at a lower level than students from other academic majors. This research will highlight students from what academic majors have better geospatial thinking and thus those disciplines may well become vehicles for improving students’ spatial and geospatial thinking skills.

Research on sex differences in spatial abilities has been ongoing since 1970s, especially in the field of psychology. Research about geospatial thinking is relatively new in such fields as geography. Although geographers and other scholars have examined many different facets of geospatial thinking, including the effects of sex/gender, and age and grade level (progression from novice to expert in school), not a great deal of literature exists for group differences in geospatial thinking based on culture, disability, socioeconomic status, academic major, academic classification, geography academic experience, ethnicity, language, or urban/rural background.

Researchers such as LeVasseur (1999), Hardwick et al. (2000), and Lee (2005) found no significant sex differences in a variety of spatial and geospatial tasks in their research studies. Studies undertaken by Allen (1974), Henrie et al. (1997), Cherry (1991), Cochrane and Wheatley (1988), Lawton (1994), and Montello et al. (1999) detected significant sex differences on various spatial tests with males performing better than females. Gilmartin and Patton (1984) and Franck et al. (1993) found significant sex differences in younger age groups such
as junior high (males outperformed females) but no sex differences in college students on various map use experiments. Voyer, Voyer, and Bryden (1995) found sex differences increase significantly with age on six distinct spatial tests. Levine et al. (2005) identified significant sex differences in middle and high socioeconomic groups (boys outperformed girls), but no differences in low socioeconomic group on certain spatial tasks. Several scholars such as Henrie et al. (1997), Newcombe and Huttenlocher (1996), Battersby, Golledge, and Marsh (2006), Marsh, Golledge, and Battersby (2007), Golledge, Marsh, and Battersby (2008), Lee and Bednarz (2012), and Huynh and Sharpe (2009, 2012) discovered that students’ spatial and geospatial knowledge (for example map usage and spatial and geospatial vocabulary and concept usage) improves with age and increasing school years.

Hardwick et al. (2000) investigated gender differences influencing performance on a standardized test of geography knowledge of 109 undergraduate students in an introductory physical geography course and 85 students in a world geography class. Students majoring in geography did better on the test than did those having other academic majors across all gender categories. Lee and Bednarz (2012) administered the Spatial Thinking Ability Test (STAT) to a sample of 532 junior-high, high school, and university students. The scholars concluded that two universities with more geography majors scored higher than two universities with fewer geography majors.

METHODS

Few standardized tests of spatial thinking exist (NRC 2006; Huynh and Sharpe 2009, 2013). I therefore drew geospatial questions from the Spatial Thinking Ability Test (STAT) that Lee (2005) developed and employed. This test has been endorsed by the Association of American Geographers (AAG 2006), and used by researchers such as Lee and Bednarz (2009; 2012). I undertook an exploratory study in a large Texas university to gather data to evaluate geospatial thinking of undergraduate students using what I term the Geospatial Thinking Survey (GTS). Figures 1-6 in the appendix show example questions from the GTS.

The GTS included demographic and academic questions, collecting data on sex, age, ethnicity, highest educational attainment of parents, annual income of parents, state of high school graduation, academic major, academic classification, number of geography courses taken in high school and college level, and urban/rural background.

Following the demographic and academic questions, the GTS had twelve geospatial thinking questions, which were closed multiple choice questions, encompassing concepts about route finding; graph and map usage; 2-d and 3-d terrain models; spatial correlation; geographic information presented as points, lines, and areas; and map overlay. Using a map, the final question asked students to engage in site analysis based on given geographical criteria.

In the fall 2012 semester, I introduced my study to undergraduate students in five general education geography courses to try to obtain as many non-Geography majors in the survey as possible. The students used the URL provided to them to complete the GTS via Survey Monkey. Participation was voluntary and anonymous. Seventy-seven students completed the GTS online. The Institutional Review Board (IRB) approved the GTS as a non-invasive and anonymous instrument for administration to university undergraduate students.

To establish the internal consistency of the GTS, I calculated the Cronbach’s Alpha statistic that measures the intercorrelation of items or the extent to which item responses obtained at the same time correlate with each other (Lee and Bednarz 2012). The Cronbach’s Alpha for the GTS was 0.679, which signifies a low level of internal consistency in social science research. However, the results of the pilot study indicated that if one particular question (3-d terrain question) were removed
from the GTS, the Cronbach’s Alpha would increase to 0.708, a value indicating an acceptable level of internal consistency among the items (Lee and Bednarz 2012). Out of a total of 77 students in the pilot study, only 20 answered the 3-d terrain question correctly. I, therefore, deleted this question from the GTS for analyses.

The dependent variable in my study was geospatial thinking, measured by the score on the GTS. The independent variables were academic major, academic classification and number of college geography courses. To analyze group differences in geospatial thinking for the three independent variables, I used one-way Analysis of Variance (ANOVA) tests to compare means on a quantitative Y outcome variable (GTS score in this case) across two or more categorical groups of X predictor variables (Park 2009). I carried out three series of ANOVAs incorporating the four predictor variables: academic major, academic classification, number of high school geography courses, and number of college geography courses. For each of these variables in different runs, the ANOVA test compared the means of various categorical groups (e.g. freshman, sophomore, junior, and senior for academic classification).

**ANALYSIS AND DISCUSSION**

Table 1 shows the distribution of respondents according to academic classification.

<table>
<thead>
<tr>
<th>Academic Classification</th>
<th># of Students</th>
<th>% of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman (First Year)</td>
<td>9</td>
<td>11.69</td>
</tr>
<tr>
<td>Sophomore (Second Year)</td>
<td>22</td>
<td>18.57</td>
</tr>
<tr>
<td>Junior (Third Year)</td>
<td>28</td>
<td>36.36</td>
</tr>
<tr>
<td>Senior (Fourth Year)</td>
<td>17</td>
<td>22.08</td>
</tr>
<tr>
<td>Graduate</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Total</td>
<td>77</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2. Group means for academic classification.

<table>
<thead>
<tr>
<th>Academic Classification</th>
<th>Total Possible Score</th>
<th>Highest Score</th>
<th>Lowest Score</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman (First Year)</td>
<td>11</td>
<td>10</td>
<td>0</td>
<td>6.11</td>
</tr>
<tr>
<td>Sophomore (Second Year)</td>
<td>11</td>
<td>11</td>
<td>2</td>
<td>7.68</td>
</tr>
<tr>
<td>Junior (Third Year)</td>
<td>11</td>
<td>11</td>
<td>3</td>
<td>8.00</td>
</tr>
<tr>
<td>Senior (Fourth Year)</td>
<td>11</td>
<td>11</td>
<td>4</td>
<td>8.82</td>
</tr>
</tbody>
</table>
was the highest of the three groups (Table 4). In this pilot study, geography majors show significantly better performance than non-geography majors. In my small sample drawn from one university, science majors tended to score better than education and business majors. This finding confirms the inferences drawn by Hardwick et al. (2000) and Lee and Bednarz (2012) about geography exerting a positive influence on the geospatial thinking of students. Geography students have better spatial and geospatial thinking than other students. This is because geographic thinking and reasoning revolves around such spatial concepts as scale transformation, spatial association, distance and direction changes, and location identification (Golledge 2002; Cutter, Golledge, and Graf 2002). My study empirically supports the theoretical assertions of such scholars as Blaut (1991), Downs (1994), Uttal (2000), Golledge (2002), and Liben (2006) that geography education is the most important vehicle in instilling spatial and geospatial thinking skills in students. A large-scale study with a bigger sample size will be necessary to determine the significance of this finding.

Table 5 displays the number of college geography courses the respondents had taken. The ANOVA (sig. value 0.017) found a statistically significant difference among the groups of geography academic experience at the college level. The mean score of the students who had taken three-five college geography courses (8.76) and students who had taken more than five geography courses at the college level (8.73) differed from students who had taken fewer than three college geography courses (Table 6). The number of college geography courses taken influences students’ geospatial thinking. This implies that with higher number of geography courses, students develop expertise in geographical thinking and thus their spatial and geospatial thinking skills improve. Higher number of geography classes provides sophisticated spatial understanding, thereby supporting Liben’s (2006) assertion that geography courses have the potential to serve as an intervention in improving geospatial thinking.

Battersby, Golledge, and Marsh (2006) reasoned that, because geography relies on many aspects of spatial thinking, reasoning, and visualization, lessons in the subject should bring about improvements in geospatial thinking skills. The findings of this study strongly suggest that to ensure students

<table>
<thead>
<tr>
<th>Academic Major</th>
<th># of Students</th>
<th>% of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geography</td>
<td>26</td>
<td>33.77</td>
</tr>
<tr>
<td>Social Science</td>
<td>3</td>
<td>3.9</td>
</tr>
<tr>
<td>Natural Science</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Humanities</td>
<td>4</td>
<td>5.19</td>
</tr>
<tr>
<td>Education</td>
<td>18</td>
<td>23.38</td>
</tr>
<tr>
<td>Business</td>
<td>3</td>
<td>3.9</td>
</tr>
<tr>
<td>Engineering</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Teacher Certification</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td>Other</td>
<td>20</td>
<td>25.97</td>
</tr>
<tr>
<td>Total</td>
<td>77</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5. Distribution of respondents according to number of college geography courses.

<table>
<thead>
<tr>
<th># of College Geography Courses</th>
<th># of Students</th>
<th>% of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never had a geography course</td>
<td>6</td>
<td>7.79</td>
</tr>
<tr>
<td>1-2</td>
<td>39</td>
<td>50.65</td>
</tr>
<tr>
<td>3-5</td>
<td>21</td>
<td>27.27</td>
</tr>
<tr>
<td>&gt;5</td>
<td>11</td>
<td>14.29</td>
</tr>
<tr>
<td>Total</td>
<td>77</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 4. Group means for academic major.

<table>
<thead>
<tr>
<th>Academic Major</th>
<th>Total Possible</th>
<th>Highest Score</th>
<th>Lowest Score</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geography</td>
<td>11</td>
<td>11</td>
<td>5</td>
<td>8.88</td>
</tr>
<tr>
<td>Education</td>
<td>11</td>
<td>9</td>
<td>0</td>
<td>6.22</td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
<td>11</td>
<td>2</td>
<td>7.82</td>
</tr>
</tbody>
</table>
are capable of competing globally in various employment areas (e.g., logistics, transportation, image analysis, GIS, civil engineering, real estate, site analysis, military operations) that require solid geospatial thinking skills, geography must be integrated into fundamental aspects of K-16 education. Students from other majors, such as nursing, education, criminal justice, and business, may be confronted with spatial and geospatial thinking in their work, but they will not be equally competent. Even if a student does not want a career in geography, taking college geography courses is important to prepare students for many other careers that require spatial and geospatial thinking skills.

**CONCLUSIONS**

An exploratory study with a small sample from one university cannot provide clear results as to which variables significantly influence geospatial thinking of students, although the study serves to guide further research. For example, the findings of this present study must be strengthened and confirmed by conducting research with a larger sample size, encompassing a larger geographical area, including more variables, and assessing the effect of different variables in combination along with considering them discretely. Geospatial thinking of American students may be compared with students in other countries for assessing cultural differences at an international scale. Understanding group differences in geospatial thinking will assist in detailing varying learning strategies.

Understanding differences in spatial and geospatial thinking competencies among various groups of students are important considerations in geography education research. The findings of this exploratory study support earlier research showing increased spatial and geospatial thinking with increasing years of experience in school and in life in general, and also reinforce the potential of geography learning to improve geospatial thinking of students. Geography students scored higher on the GTS than non-geography majors. Moreover, students who studied more geography courses performed better on the GTS than students who studied few geography courses. This study underscored the importance of geography education in improving students’ spatial and geospatial thinking. It highlighted that non-geography major students should also take a few geography courses in college so that they will be competent both in school and in the workplace with higher geospatial thinking.

**REFERENCES**


_______. 2012. Components of spatial thinking: Evidence from a Spatial Think-
APPENDIX

1. The map below shows average annual precipitation of Texas. If you draw a graph showing change of Texas annual precipitation between A and B, The graph will best match which curve?

- A
- B
- C
- D
- E

Figure 1. Selected Questions from Geospatial Thinking Survey (GTS): Question 1 focusing on Geospatial Pattern and Transition (Access all questions at https://sites.google.com/site/geospatial2013gts/home/geospatial-thinking-survey)
2. Please answer this question on the basis of the street map below. If you are located at point 1 and travel north one block, then turn east and travel three blocks, and then turn south and travel two blocks, you will be closest to which point?

- 2
- 3
- 4
- 5
- 6

Figure 2. Selected Questions from Geospatial Thinking Survey (GTS): Question 2 focusing on Map Navigation, Way-finding, Route Planning, and comprehending Orientation and Direction (Access all questions at https://sites.google.com/site/geospatial2013gts/home/geospatial-thinking-survey)
3. Imagine you are standing at location X and looking in the direction of A and B. Among five slope profiles (A – E), which profile most closely represents what you would see?

- A
- B
- C
- D
- E

Figure 3. Selected Questions from Geospatial Thinking Survey (GTS): Question 3 focusing on Geospatial Profile and Transition (Access all questions at https://sites.google.com/site/geospatial2013gts/home/geospatial-thinking-survey)
4. Find a map (A – F) having a strong positive correlation (association or showing similar pattern) with the top map on the right. Choose the closest one.

- A
- B
- C
- D
- E
- F

Figure 4. Selected Questions from Geospatial Thinking Survey (GTS): Question 4 focusing on Geospatial Association and Correlation (Access all questions at https://sites.google.com/site/geospatial2013gts/home/geospatial-thinking-survey)
Real-world objects can be represented by points, lines (arcs), and areas. Based on the examples in the figure below, classify the following spatial data in the following question:

5. Location of weather stations in Washington County.
   - Lines
   - Area
   - Points and Lines
   - Points

Figure 5. Selected Questions from Geospatial Thinking Survey (GTS): Question 5 focusing on identifying and comprehending Geospatial Shapes—integration of geographic features represented as points, lines (networks), areas/polygons (regions) (Access all questions at https://sites.google.com/site/geospatial2013gts/home/geospatial-thinking-survey)
6. Find the best location for a flood management facility based on the following conditions.

First, a possible site for a flood management facility should be within 60 feet of an existing electric line.

Second, a possible site for a flood management facility should be located less than 220 feet in elevation.

And last, a possible site for a flood management facility should be located in state park or public land.

Choose the best site (A–E) for the flood management facility on the potential facility location map.

- A
- B
- C
- D
- E

Figure 6. Selected Questions from Geospatial Thinking Survey (GTS): Question 6 focusing on Geospatial Overlay—comprehending overlaying, aggregating, and dissolving map layers to choose the best location based on various spatial/geographical conditions, connections, distance; inferring a geospatial aura (influence) (Access all questions at https://sites.google.com/site/geospatial2013gts/home/geospatial-thinking-survey)