Integrating GIS in the Middle School Curriculum: Impacts on Diverse Students’ Standardized Test Scores

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ABSTRACT
This case study conducted with 1,425 middle school students in Palm Beach County, Florida, included a treatment group receiving GIS instruction (256) and a control group without GIS instruction (1,169). Quantitative analyses on standardized test scores indicated that inclusion of GIS in middle school curriculum had a significant effect on student achievement on both high stakes Florida Comprehensive Achievement Test (FCAT) reading scores and on final course grades in science and social studies. The most significant increases were found among the English language learners (ELLs).

Key Words: assessment, attitudes, geographic information systems, technology, diversity

INTRODUCTION
A growing number of authors suggest that inclusion of geographic information systems (GIS) into school curricula promotes learning and development of students’ critical thinking skills, analytical abilities, and communication skills (Kerski 2001; Alibrandi 2003; Hagevik 2003; Johansson 2003; Bloom and Palmer-Moloney 2004; Bednarz and Van Der Schee 2006; Pang 2006; Milson and Alibrandi 2008). GIS is one component of geospatial technology, which also includes remotely sensed imagery, global positioning systems, and virtual globes. Each component has different strengths and weaknesses for the classroom, but the use of GIS is the focus of this study.

While previous studies suggest that there are pedagogical benefits of GIS in the K–12 school curriculum, a documented relationship between GIS instruction and student academic achievement using standardized test measures is lacking (Hagevik 2003; Johansson 2003; Bloom and Palmer-Moloney 2004; Pang 2006). The analysis and findings from this study present a comparison of student performance in both GIS (treatment) and non-GIS (control) groups’ standardized test score data as well as final science and social studies end-of-course grades.

Palm Beach County School District in southeastern Florida is the eleventh largest school district in the nation. The school district encompasses the entire county (over 2,000 square miles) and has a very diverse student population. Palm Beach County has been viewed as a microcosm of the nation in terms of demographics (Carmona, Wheelock, and First 1998). As of 2010 the county’s population had become “majority minority,” confirming the statement by Crouch and Banks Zakariya (2007) that “trends in immigration and birth rates indicate that soon there will be no majority racial or ethnic group in the United States.” Over 170,000 students speak 149 languages and dialects other than English in the district (Palm Beach County School District 2009). The county’s population is mostly middle and lower socioeconomic class. Over 48 percent of district students qualify for free and reduced meals, a breakfast and lunch program sponsored by the government for lower socioeconomic status children (Goldstein 2008).

Traditionally, students of color and English language learners (ELLs) have performed poorly in science and social studies (Reed and Railsback 2003; Doherty et al. 2003). While testing in these subjects is not included in the Florida comprehensive achievement test, end-of-course grades were analyzed to determine if these groups of students benefitted from receiving GIS instruction. For students of lower socioeconomic status, learning GIS in grade school can afford enhanced and applied computer literacy skills. Belcher (2001, 1) suggests that “for many disadvantaged youths, having access to computers and learning valuable, marketable skills can be a ticket out of poverty.” Pang (2006, 3) reinforces this by stating that “GIS use in education will develop students’ information and media literacy, preparing them well for the digital age.”

STUDENT LEARNING WITH GIS
GIS as a Pedagogical and Learning Enhancement
GIS instruction facilitates students’ manipulating, querying, summarizing, and editing spatial data and provides the tools for spatially analyzing these data and any resulting patterns. The power of student learning with GIS lies in their ability to perform functions such as spatial querying, statistical analysis, and visualization. In other words, they learn to ask geospatial questions and search...
Addressing the Achievement Gap

Infusing GIS into instruction also incorporates multiple intelligences, thus broadening the spectrum of students that can be reached academically. Gardner (2004) describes how each “intelligence,” having its own symbol system such as words, maps, or numbers, and corresponding patterns, can be transferred across the intelligences. The very nature of GIS activates students’ “multiple intelligences” as described by Gardner (2004). Multiple intelligences theory “posits that intelligence is not uniform, and that people possess at least eight exclusive intelligences including the musical, bodily kinesthetic, logical mathematical, linguistic, spatial, interpersonal, intrapersonal and naturalistic” (Bloom and Palmer-Moloney 2004, 2). These intelligences, which influence the various ways in which learning is absorbed, retained, and transferred, are activated by using GIS through reading (linguistic intelligence), mapping (spatial intelligence) and analysis (logic-mathematical intelligence).

In this study, the GIS intervention groups actively engaged a number of intelligences while performing the activities in the GIS lessons. Each had their own PC but many collaborated, thus using both intrapersonal and interpersonal skills. The spatial data lends itself to aspects of the naturalist intelligence and the visual, spatial, and mathematical intelligences at the core of the lessons. For example when learning about mortality rates and agriculture production, students performed statistical functions and analyzed the numbers to determine if there was a correlation. Tapping into visual intelligence may be especially beneficial for English language learners.

Studies in visual literacy have demonstrated that computer visualizations, representations, and animations all contribute to improved comprehension. Pan and Pan (2009) studied English as Foreign Language learners (EFLs) and grounded their study in Johnson-Laird’s Mental Models (1983) and Paivio’s Dual Coding Theory (1986). When addressing second language learners Paivio emphasizes understanding mental processing, noting the vital role that using visual and spatial skills may have on thinking and comprehension. According to Paivio, we maintain mental images and words as separate functions and by separate codes. For new language learners, the visual referents (called imagens) provide support to both languages in a bilingual or multilingual person. In the way that the image of a cup of coffee represents the item, it is language independent; the perceiver (in this case, an ELL middle schooler) can identify the item at a glance. This fires an entire schema around coffee-images and related words such as coffee cup, taste, flavor, aroma, coffee beans, perhaps coffee plants or plantations, etc. The visual image therefore excites multidimensional related imagery that can now be represented and verbalized in the second language.

In the case of GIS maps as visual images, students are encountering the new maps in the second language, therefore enhancing their grasp of the visual, spatial, and linguistic relationships as a whole schema. The benefits for second language learners are multiple, and include enhanced comprehension and mastery. This new visual-spatial-linguistic GIS schema has little relationship to preexisting language knowledge since it is being learned
in the context of English. In this process, new imagery, words, concepts, and applications are being activated simultaneously, thereby strengthening the retention of each.

Normally, social studies and science are highly laden with sophisticated terms (and new place names), so familiarity with spatial representations of both geographic and environmental phenomena such as those in the GIS classes were enhanced by the visual-spatial-linguistic relationships. Thus Dual Coding Theory (Paivio 1986), which also underlies geospatial software development, better matches and enhances the learning of language as well as the discipline-based content.

The positive effect of pictures, as depicted by the GIS maps and other visual images, on reading comprehension revealed in this study can be further explained by Johnson-Laird’s (1983) theory of mental models. According to Johnson-Laird, visuals can reduce the cognitive load in complex tasks because they can present essential information more concisely than equivalent textual statements. As a result, visuals facilitate mental model building. In this study the pictures represented in maps were easier to process than text because they show spatial relations and help readers construct internal representations (Pan and Pan 2009). In 2009 Pan and Pan found similar results to those in this study, with an increased degree of improvement also demonstrated by EFL (English as a Foreign Language) students.

GIS for Improving Vocational Opportunities

In addition to the pedagogical benefits highlighted by this study, introducing GIS into the classroom provides students with marketable skills and enhances their future career prospects. The U.S. Department of Labor has recognized that geospatial technology skills have become more prominent in various industries and reported that “employment growth of 18 percent is expected for geoscientists and hydrologists between 2008 and 2018, which is faster than the average for all occupations” (U.S. Department of Labor 2009, 4). Pang (2006, 1) suggests that the learner-centered approach to delivering curriculum through GIS enhances the overall learning experience for students and encourages students to actively participate in manipulating data and constructing and presenting information. Pang further states that “the skills and knowledge students acquire through GIS use in school may also enhance their future career prospects.” Her comment supports the necessity to educate our students with the skills they will need to compete in the global marketplace.

METHOD

GIS Instruction

This case study reports the results from two different courses. For the initial introduction of GIS into this middle school, GIS was infused into a traditional social studies course where GIS lessons were introduced and taught twice a week for two semesters during 2007–08. The GIS instruction during these classes included social studies lessons contained within the Mapping Our World GIS lesson book. The second course was introduced as a GIS elective class and was taught five days a week for two semesters in 2008–09. The instruction occurred at one middle school in the Palm Beach County School District. The teacher involved in this study received a two-day staff development training workshop in the use of GIS from the Mapping Our World GIS lesson plan book (Malone et al. 2005). The middle school classroom where she taught was configured as a PC lab so that each student would have an individual PC on which to work through the GIS lessons. The GIS lessons involved data both from local sources and worldwide data sets.

The GIS lesson plans used can be particularly advantageous for students who speak English as a second language, as many of the GIS lessons use worldwide data. These students are more inclined to be motivated for learning when the content-rich material can be tied to their home countries and heritage. For example, students from South America can click on their home country polygon in the GIS map and see all of the data associated with that country. It is a widely held belief that when teaching ELL students the inclusion of their backgrounds, culture, and heritage is extremely advantageous to their instructional comprehension. One of the five standards for student achievement developed by Tharp et al. (as cited in Doherty et al. 2003, 4) is based on sociocultural tenets that “instructional activities are meaningfully connected to students’ prior experience and knowledge.” As noted by Reed and Railsback (2003), culture studies can be combined with other strategies such as project-based learning, cooperative learning, and accessing a student’s prior knowledge.

Accessing the worldwide data sets as part of the GIS lessons helps to provide a connection to their homelands and often sparks a new interest in learning. For all other students in the class who are not ELL, this provides an opportunity to learn about where the ELL students were from, prompting dialogue and learning.

Many of the lessons for the elective class revolved around science and social studies activities such as earthquakes, hurricanes, and population growth. Students performed tasks that helped them understand patterns and the effects that natural and human-made activities have on the human population such as flooding, the loss of homes from hurricanes, or declining agricultural productivity. Other projects used local data and places of interest to the students such as movie theaters, restaurants, and bowling alleys. The data was relevant for the students and the interactive platform of working with graphics and spatial data on the computers engaged them in the learning process. Students collaborated spontaneously, working together to solve problems. At different stages of the lesson students submitted PDF maps depicting the analysis required in the activities. They also participated in a number of discussions and took quizzes that assessed vocabulary, theory, and
practical GIS knowledge. The science and social studies curriculum contained within the lessons, as well as learning complex technical processes, added to the student’s critical thinking capabilities and assisted them in honing problem-solving skills.

**Research Participants**

The study included those students with treatment (the elective class students and the infusion-model social studies students) and the control group for each (students without GIS instruction). The treatment group consisted of a total 256 students who received GIS instruction and 1,169 students in the control group who did not receive GIS instruction. The demographic composition for both groups was similar, and representative of the entire school district (Goldstein 2010).

For students in the GIS elective class, GIS had not necessarily been their first choice. Due to classroom space constraints, students are often placed in electives out of convenience. For the fall semester of 2008, approximately 50 percent of the students actually selected the GIS class as their elective. However, for the spring 2009 semester only 10 percent of students who were in the GIS elective course had selected it as their preferred elective. Therefore, 90 percent of the students had been randomly placed into the GIS elective classes. For the GIS infusion model in the social studies class, students did not have an option as it was part of their required curriculum. There, the GIS curriculum was taught twice each week.

**RESULTS**

The academic achievement variables under investigation included GIS instruction versus no GIS instruction, race, students who speak English as a second language, and the average test scores for Florida’s Comprehensive Assessment Test (FCAT) in reading. For the academic achievement analysis, multiple regression, t-tests, and ANOVAs were performed to test for relationships among the variables.

To assess practical significance, a critical effect size of 0.10 was used. A critical effect size of 0.10 is considered a small to moderate effect according to Cohen (1992), with 0.10 the smallest effect that might warrant a policy change. An effect size of 0.10 indicates that 10 percent of the variance in the dependent variable is accounted for by the linear model. To assess practical significance, $\eta^2$ was chosen as the effect size measure. The probability of making a Type I error is equal to the alpha level, therefore, if the alpha level is set to 0.05 the probability of making a Type I error is 0.05. For all inferential tests performed on a set of data, the probability of making a Type I error is additive. When conducting a second t-test on part of that same dataset, the probability of a Type I error on either or both tests is now twice, or 0.10, because the probability of making a Type I error was 0.05 for each test. One way to minimize making a Type I error over multiple t-tests is by adjusting the alpha level for each t-test. This is known as the Bonferroni correction.

**FCAT Reading Analysis: by Race and Native Non-Native English-Speaking Students**

Two t-tests were used to compare student FCAT reading scores and final class grades in science and social studies between students who had GIS instruction and those who did not. To avoid an increase in the risk of a Type I error (making a false claim that the null hypothesis should be rejected when it is true in the population) when multiple hypotheses are tested, the Bonferroni correction, which in this case was an adjustment of the alpha level to 0.025 for the individual hypothesis tests, was applied to maintain an overall 0.05 alpha level.

For both white students and non-white students, the difference in average FCAT reading scores between GIS treatment and non-GIS control students was statistically significant (Table 1). The FCAT reading scores are significantly higher for those students with GIS instruction compared with those students without GIS instruction.

Non-native English-speaking students who took GIS showed higher FCAT reading scores. The average FCAT reading score for native English-speaking GIS students was significantly higher than the average FCAT reading scores of non-GIS non-native English-speaking students (Table 2). The average FCAT reading score for native English speaking non-GIS students was also significantly lower than the average FCAT reading score of native English-speaking GIS students. In the analysis of this study’s findings, there was a significant increase in FCAT reading scores for both groups as viewed through the variable of native language.

<table>
<thead>
<tr>
<th>Group</th>
<th>M</th>
<th>SD</th>
<th>N</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCAT Reading</td>
<td>GIS</td>
<td>343.35</td>
<td>46.83</td>
<td>107</td>
<td>2.69</td>
<td>654</td>
<td>0.000*</td>
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<tr>
<td></td>
<td>Non-GIS</td>
<td>320.19</td>
<td>59.14</td>
<td>549</td>
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<tr>
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<td></td>
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<tr>
<td>FCAT Reading</td>
<td>GIS</td>
<td>333.07</td>
<td>42.86</td>
<td>70</td>
<td>4.125</td>
<td>643</td>
<td>0.000*</td>
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<tr>
<td></td>
<td>Non-GIS</td>
<td>305.12</td>
<td>48.03</td>
<td>575</td>
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</tbody>
</table>

* $p < .025$.
Table 2. Effect of groups on moderation of FCAT Reading scores by primary language.

<table>
<thead>
<tr>
<th>Source</th>
<th>Group</th>
<th>M</th>
<th>SD</th>
<th>N</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>(\eta^2)</th>
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</thead>
<tbody>
<tr>
<td>FCAT Reading: State GIS</td>
<td>340.27</td>
<td>41.82</td>
<td>44</td>
<td>12.98</td>
<td>380</td>
<td>0.000*</td>
<td>0.307</td>
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<td>FCAT Reading: Non-GIS</td>
<td>246.46</td>
<td>45.49</td>
<td>338</td>
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<table>
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<th>Source</th>
<th>Group</th>
<th>M</th>
<th>SD</th>
<th>N</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>(\eta^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCAT Reading: State GIS</td>
<td>344.38</td>
<td>47.33</td>
<td>133</td>
<td>16.2</td>
<td>917</td>
<td>0.000*</td>
<td>0.222</td>
<td></td>
</tr>
<tr>
<td>FCAT Reading: Non-GIS</td>
<td>260.09</td>
<td>56.77</td>
<td>786</td>
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</tbody>
</table>

\* \(p < .025\).

In 2009 the state of Florida average FCAT Reading score for middle school students was 315, where a scale score over 300 is considered passing.

**Science Grade Analysis**

Additional analysis was performed to identify which differences between averages of science grades were significant when analyzed by race. A t-test was performed for non-white student data, both those who had GIS instruction and those who did not. With science grades as the criterion variable and race as the moderating variable, results were statistically significant for non-white students. Table 3 shows that the average science grade for non-white non-GIS students, 3.36, was significantly lower than the average science score of non-white GIS students, 4.06. These results indicate an increase in final science grade from B to A.

A t-test was also performed on white students, both those who had GIS instruction and those who did not. Table 3 shows that the average science grade for white non-GIS students, 3.81, was not significantly lower than the average science score of white GIS students, 3.94. These results indicate only slightly higher final scores for those white students who had GIS instruction; both groups averaged a final science grade of B.

**Social Studies Grade Analysis**

A comparative analysis was performed to determine if the frequency of GIS instruction had an effect on social studies grades. In Table 4, the difference in average social studies grades between those who received GIS instruction twice a week in the GIS infusion model and those who had GIS instruction five times a week as a GIS elective class was statistically significant. No students had both conditions; the instruction was conducted in different semesters. Those students who had GIS instruction five times a week in the elective class and also received a traditional social studies curriculum course outperformed students who had no elective GIS class and received GIS instruction as part of their social studies class twice a week.

**DISCUSSION OF FINDINGS**

The findings indicate that inclusion of GIS in middle school curriculum had a significant effect on student achievement. These findings established a significant link between GIS integration and academic performance on standardized test scores. In this study, standardized FCAT reading test results and science and social studies final grades indicated that GIS integration enhanced student learning and academic achievement.

In particular, English language learners (ELLs) are specifically identified as a subgroup that has fallen behind academically. Under Title I of No Child Left Behind (NCLB), K–12 schools, districts, and states are held accountable for an annual increase in academic achievement for ELLs. Title III of NCLB establishes the additional requirement to demonstrate that ELLs are making continuous progress in English language development. The NCLB accountability expectations for academic achievement are measured through standardized tests such as the Florida Comprehensive Achievement Test (Harper et al. 2007). In this study ELLs in the GIS treatment group demonstrated gains in the FCAT reading scores.

There was a positive relationship between GIS instruction and student performance on the FCAT reading test. The findings indicate that the average test scores of GIS students were higher than those of non-GIS students. Although these findings had a small effect, it is sufficient to warrant district policy change.

These results underscore the potential benefit GIS may have on academic achievement, especially for minority and English language learners (ELLs). The actual length of time students were exposed to GIS was brief, only one semester. Since the relationship does appear despite the brief exposure, the
potential exists for a stronger relationship between GIS instruction and academic achievement, which might be realized after students have experienced additional GIS instruction throughout their development and matriculation.

Another indicator that learning GIS transferred to other areas was demonstrated by the elevated FCAT reading scores, the gains in science for non-white students, and the gains in social studies for students who received GIS instruction five times a week compared to those who received GIS instruction twice a week. If reading is central to learning, and if GIS integration positively impacts reading scores, this learning may be transferred to other topics as well. Students may construct new knowledge in other subjects by building upon the gains in reading related to the GIS instruction. This outcome may also be a residual effect of the students actually being engaged in the learning and motivated to comprehend and understand the lessons. As their culminating assessment, students in the GIS elective class employed problem-based learning for local GIS projects. For these, students generated and applied new data from environmental and local census data. This, therefore, expanded into the curricular areas of science and social studies.

**IMPLICATIONS AND CONCLUSION**

The social and financial implications of geospatial technologies, including GIS, prompted the U.S. Department of Labor to identify geospatial technology as one of the three most important emerging and evolving fields (Gewin 2004). This is important for workforce preparation. But at least equally important is the use of GIS as a learning tool.

In this study, a correlation was found between GIS instruction and an increase in standardized test scores. There is an indication that the learning achieved during GIS instruction was transferred to other cognitive and discipline areas as demonstrated by FCAT reading scores for GIS treatment students compared to the control group. This is an area that requires further study and analysis. Since literacy was Florida’s highest priority in testing schemes, the impact of spatial analysis and computer literacy on basic literacy (reading) highlights a need for further investigation. It also appears that the GIS instruction had a positive impact for learning gains in science and social studies. Based on these outcomes, further efforts to integrate GIS into the curriculum and measure those results are merited.

While the results of this case study substantiate the value of implementation of GIS instruction in K–12 education, the extent of academic benefits to students requires continued research and longitudinal study. The findings from this study provide evidence that integrating GIS in curriculum may be one way to engage students in the learning process and raise the literacy and intellectual capacity of our youth. Future research may also include a longitudinal study that follows students who have had GIS instruction over a series of years. Results of such studies may reinforce the initial findings reported herein. In addition, the interactions between GIS instruction, multiple intelligences, and other disciplines are worth further exploration. Additional studies concerning high-stakes test results may also be utilized to educate legislators and school administrators on the academic benefits of GIS for K–12 education institutions.

**REFERENCES**


