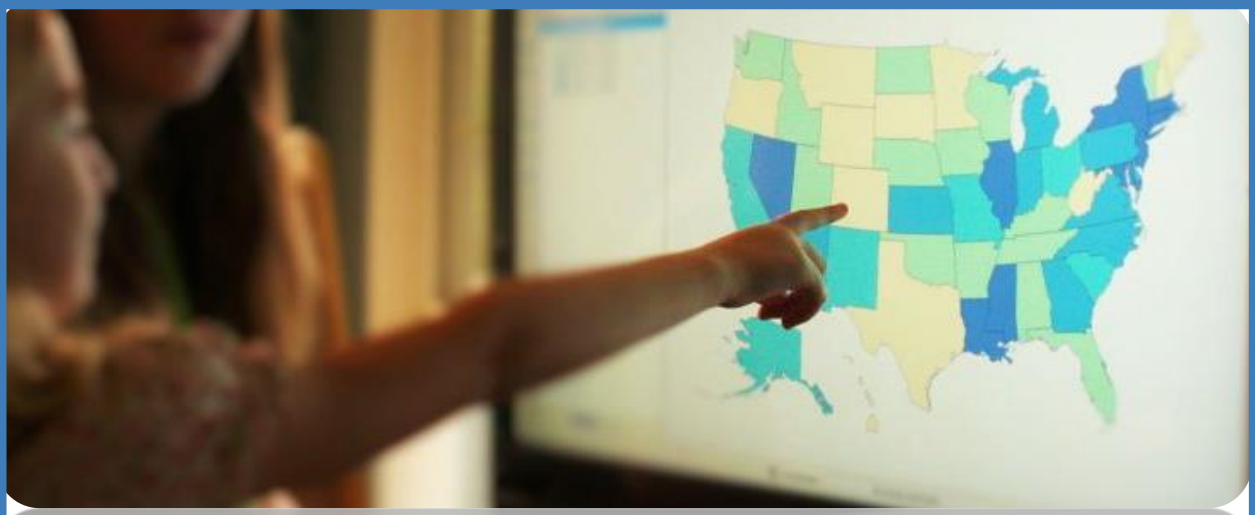

NATIONAL SCIENCE FOUNDATION STUDY

GIS In Elementary Schools

STUDY REPORT

JANUARY 2016

ILLINOIS STATE UNIVERSITY GIS EDUCATION TEAM

GIS Study Report

*National Science Foundation Study**

Illinois State University GIS Education Team | Normal, IL | January 2016

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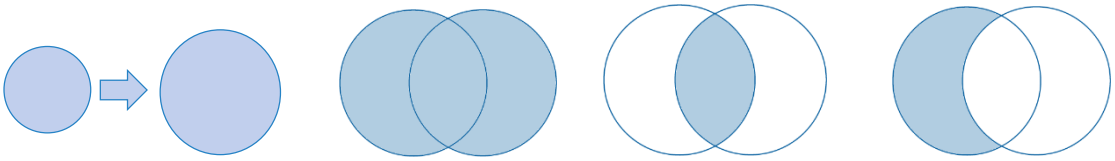
Curriculum

Six modules featuring cross-curricular activities integrating technology, history, geography, ecology, science, and language arts were created to promote fifth grade students' higher-level thinking skills. The modules utilize Geographic Information Systems (GIS) to help students manipulate data represented as layers of maps using a variety of tools. The tools are based on set theory functions that are considered the basis of modern mathematics.

Module One: Set Theory Primer

Students are introduced to the four functions below in a number of engaging activities before they are introduced to GIS technologies.



Buffer
The increase of space around a layer

Union
The combination of two layers into one

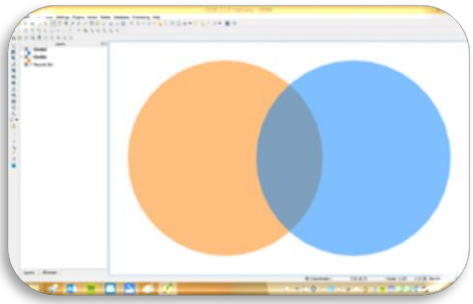
Intersect
The space two layers have in common

Difference
The space that is unique to one layer

Module Two: Venn Diagrams

Students are introduced to QGIS software and learn how to correctly use a computer and a flash drive. The students learn how to open the QGIS program, save projects, retrieve projects, and complete a task on a project.

Most importantly, using two very simple layers in QGIS, students learn how to perform set theory operations which they learned in Module One.



Module Three: Illinois State Capitol

In this module, students encounter the first problem-solving challenge! In celebration of Arbor Day, students are asked by the Governor of Illinois to plan a new tree on the Capitol grounds.

The students manipulate five layers of maps to find a good location for a new tree. Below is an example written by one student as a concluding activity in 2014.

Dear Governor,

My name is Larry Robinson. Congratulation on winning Governor! I think the best spot is east from the front of the Capital and then go a little bit south. The reason why I found this spot is I did the following. First I used buffer to buffer the asphalt, The Capital building, and the sidewalks in the length to roles stated. So that ruled out sum spots. Then I united all the things I didn't want. Next I intersected all the good things I wanted the tree to be by. Then I used difference to take away the bad things from the good but still ensuring the rules are being followed. But that last layer made spots that would be great. Then I saw the spot, it was close to the capital but not too close and it was close to the sidewalks so people could see it; it had its own space so it could grow and still be seen. So this is why I think this spot is the best spot to plant the tree.

Sincerly,

Larry Robinson (pseudonym)

Module Four: Box Turtle

Students work on the second challenge, this time they work to find a good place to release a lost box turtle back to its habitat in the state of Illinois.

The students read a variety of text genres to learn about the ecology of box turtles including: informational text and fiction.

The students manipulate a larger set of map layers using set theory functions, working more independently than in the previous module. Finally, students check the locations they determined using Google Earth as well.

Module Five: Bighorn Sheep

This module takes the students to Utah! This time, the challenge is to relocate a herd of bighorn sheep to a protected area away from different sorts of threats.

The students interact with a 14 layers of maps and use the GIS tools to find the best place to relocate the herd. Similar to the previous module, students learn scientific facts about bighorn sheep using a set of both informational and fictional texts.

Module Six: The Revolutionary War

Working independently, students identify battles that America won and lost against the British. They consider bodies of water, mountains, forests, and nearby cities that can affect soldiers and civilians.

Students find solutions to simple challenges using the set theory operations they learned in module one.

Primary Goals

Our multi-disciplinary curriculum has a number of core goals. We aim to help students develop the following capacities:

- Understand spatial relations and their meanings
- Approach problems holistically
- Predict solutions and work towards configuring them through a logical multistep approach
- Utilize resources effectively
- Work collaboratively with peers in a productive and meaningful manner
- Depend increasingly on self and peer collaboration, consulting with teachers only when progress cannot be otherwise achieved.

Targeted Cognitive processes

Out curriculum aims to target and develop the following higher-level thinking processes:

- **Logical multistep reasoning:** to achieve X, we start with A, which leads to B, which leads to C, that will achieve X
- **Analogical reasoning:** how the superficial and deep features of event A are similar or different from event B, and how this comparison can help advance a solution to problems
- **Hypothetical thinking:** considering imaginary scenarios in the process of responding to challenges or providing conditions (if, then) for solutions
- **Reasoned argumentation:** the ability to consider opposing perspective and respond to them in the process of developing one's own informed views
- **Systems thinking:** the process of considering divergent systems determining possible solutions to a challenge
- **Spatial thinking:** considering spatial components while problem solving

Progress Measuring Instruments

1. **NAEP geography items**
   A pre and post-intervention NAEP (National Assessment of Educational Progress) activity has been prepared using the public-domain geography items. Both versions of the instrument have been approved by ETS (Educational Testing Service).
2. **Academic interest questionnaire**
   The academic interest questionnaire aims to measure the level of classroom engagement and interest in academics and specific modes of learning (e.g., working in groups, direct

instruction, activity-based learning) at the beginning and end of the intervention period. Of particular interest is student motivation to pursue related fields after the intervention.

3. **Use of technology questionnaire**
   The use of technology questionnaire aims to measure children's typical use of technology in the school and at home and to document any change in this use due to the GIS unit. Specific responses may also be used to track relationships between students' use of technology at home and performance on GIS activities.

4. **Independently developed transfer activities**
   Two transfer activities have been designed to measure students' ability to transfer spatial skills and problem-solving techniques developed during the GIS training to solve problems with similar structure but housed in different contexts. The activities need to be solved without the aid of the QGIS software to ensure the activity's fairness to the control group.

5. **Cognitive Ability Test (CogAT)**
   CogAT is a K-12 assessment that measures verbal, quantitative, and nonverbal reasoning. We will use the nonverbal subtests as pre, post, and delayed-post-intervention assessments.

6. **Cognitive Interview**
   This instrument is designed to measure students' ability to think collaboratively in the process of solving a spatial problem. Student responses will also be analyzed in regard to spatial references, higher-level reasoning including: hypothetical reasoning, analogical reasoning, reasoned argumentation, and systems thinking.

Curriculum Implementations

We had the great honor and pleasure of working with a number of schools districts on this study.

- Local School District: where we completed our very first pilot study in 2012-2013 focusing on 5th grade social studies' curriculum. Funded by ISU.
- Rural School District: this was our second pilot where four modules were conducted in three 4th grade classrooms in 2013-2014. Funded by NSF.
- Urban School District: We worked with seven teachers in four schools that implemented four to six modules in their classrooms in 2014-2015 and 2015-2016. Funded by NSF.

2012-2013 Local School District

- **Teachers and classrooms**: we worked with one middle grades social studies instructor and two 5th grade classrooms
- **Importance and results**: students learned the use of GIS to visually understand different layers of maps. The experimental group girls outperformed girls and boys in the control group in the paper-folding test. The experimental group did better on the transfer test.

2013-2014 Rural School District

- **Teachers and classrooms**: the 4th grade teacher team worked with us including the students in three classrooms
- **Teacher training:** training was completed on site. The curriculum developer and teacher trainer conducted the GIS modules in the classroom in the presence of the first teacher. The two other teachers were trained in two consecutive months. One teacher conducted the curriculum while the other served as a control.
- **Measurement results:** the experimental group's students did better on the NEAP test items and the transfer test. Moreover, the experimental group outperformed the control group on the cognitive interviews demonstrating a statistically significant performance in two cognitive processes: systems thinking (the ability to integrate a variety of systems in the solution of a particular problem) and reasoned argumentation (the ability to consider and respond to alternative and opposing perspectives)
- **Importance:** this pilot study allowed us to adjust our curriculum, test out our measuring instruments, and create a new training approach to the first urban district teacher cohort.

2014 – 2015 Urban School District

- **Teachers and classrooms**: We worked with one teacher and two classrooms from each school bringing the total up to four classrooms. Two of the four classrooms were trained to use the GIS in the fall semester and two classrooms were trained to use GIS in the spring semester
- **Teacher training**: 20 hours of summer training followed by 4 hours of training during the school year
- **Measurement results**: students made gains in the CogAT non-verbal spatial ability subtests and the NAEP geography items. Moreover, the students in experimental classrooms reached more accurate results in their transfer tests.
- **More results**: students' non-verbal CogAT schools were highly correlated with students' digital-gaming patterns. It was also found that students expressed clear interest in the GIS curriculum.
- **Special events**: one school organized an Open House event towards the end of the fall semester where parents and school staff were invited to see what the students learned during the QGIS training. Additionally, students developed exciting iMovie Trailers featuring the GIS curriculum. The work of this year was featured in a 3-minute video showcase that was presented by NSF in May 2015 and was watched by people in all over the world.
- **Importance:** working with the two teachers was a great success. Thanks to their suggestions, we were able to make additional changes to our summer training and we adjusted the first module to make the curriculum flow better with teachers' plans.

2015 – 2016 Urban School District

- **Teachers and classrooms:** We worked with six teachers and seven classrooms having one teacher teach two 5th grade classrooms. Four classrooms implemented GIS during the fall semester while three classrooms will complete GIS modules during the spring semester.
- **Teacher training:** the teachers had no less than 40 hours of training, 36 hours were completed during the summer followed by 4 hours of training during the school year.
- **Teacher support:** the GIS curriculum developer met with teachers two days a week to provide on-site assistance as needed. In addition, 22 short videos of GIS tutorials were developed to support teachers remotely. Those videos can be accessed through the GIS teacher website: QGISTeacher.weebly.com. This system of support was a huge improvement since last year's implementation.
- **Special Event:** One school for the second year in a row organized an Open House with a great turn out. The school invited the School District Superintendent, School Board President, School Board members. Many parents and grandparents were in attendance as well.

2015 Conference Presentations

Our team gave six conference presentations covering the spectrum of results from the first two years of the NSF project implementation.

Hund, A. M., Jadallah, M., Thayn, J., Studebaker, J., & Roman, Z. (2015, October). *Using Geographic Information Systems to improve elementary students' geography knowledge and spatial skills.* Poster presented at the Cognitive Development Society pre-conference on The Developmental of Spatial Thinking, Columbus, OH.

The October 2015 analysis demonstrates that GIS training positively impacts upper elementary students' understanding of maps as demonstrated by the NAEP geography items with a special impact on girls. All students' spatial abilities as demonstrated by their performance on the CogAT non-verbal items improved significantly.

Roman, Z., Studebaker, J., Hund, A., Jadallah, M., & Thayn, J., Gupta, K., Schloesser, D. (2015, September). *Measuring spatial thinking: Is there a reliable and valid measure?* Poster to be presented at Integrating Cognitive Science with Innovative Teaching in STEM Disciplines: Spatial Learning in STEM conference, Evanston, IL. (PDF) (prog.)

In September 2015 we compared our transfer test to a GIS high school test showing that our test was more sophisticated and focused on creative solutions. By analyzing the students' performance on a map question, we were able to demonstrate that the experimental group provided more precise and accurate solutions compared to the control group.

Jadallah, M., Hund, A., Thayn, J., & Studebaker, J. G., (2015, August). *The Impact Of Geographic Information Systems On Elementary Grade Students' Spatial Reasoning* . Paper presented at the annual meeting of the National Council for Geographic Education, Washington, D. C. (PDF) (prog.)

During the National Council for Geographic Education (NCGE) conference we gave two presentations. In the one listed above, we analyzed the written component of the transfer test. The analysis indicated that the experimental group outperformed the control group in two abilities: (1) the mental ability to manipulate map information and (2) the ability to connect and compare maps and locations, overlap maps, and realize spatial patterns.

Studebaker, J. G., Jadallah, M.,& Hund, A. M. (2015, August). *Promoting Advanced Reasoning Skills using GIS* **.** Workshop conducted at the annual meeting of the National Council for Geographic Education, Washington, D. C. (PDF) (prog.)

A workshop during the NCGE conference was given focusing on our multi-disciplinary curriculum and our focus on developing and sustaining a number of goals including: teaching students spatial relations and their meaning, considering problems holistically, predicting solutions in multiple steps, utilizing resources effectively, and cooperating with peers with fading teacher scaffolding to foster independence.

Jadallah, M., Studebaker, J. G., Hund A. M., (May, 2015). *GIS Modules to Develop Elementary Students' Spatial Thinking and Higher-level Reasoning Skills.* Presented at the annual meeting of Illinois Geographical Society; Bloomington, IL. (PDF) (prog.)

In May 2015 we presented the results of our pilot studies. One analysis focused on our first pilot study and indicated that the students in the experimental group significantly discussed spatial information that are both local and global, provided more explanations, and wrote more than the control group in the transfer test.

Jadallah, M., Lin, T., Hund, A. M., Thayn, J., Studebaker, J. G., & Mullins, S. (2015, April). *Digital Mapping Technology in Elementary Grades: Effects on Spatial Reasoning and Higher-Level Thinking Processes*. Poster presented at the annual meeting of National Association for Research in Science Teaching, Chicago, IL. (PDF) (prog.)

This presentation that was delivered at the National Council for Research in Science Teaching conference focused on our second pilot study. Our results indicated that experimental group students demonstrated higher-level thinking processes during the cognitive interviews augmented by higher results on NAEP test.

Project Websites

General Public website: education.illinoisstate.edu/nsf

Teacher Training website: QGISTeacher.weebly.com