Pyrex Journal of Educational Research and Reviews

Vol 2 (6) pp. 67-78 December, 2016

http://www.pyrexjournals.org/pjerr

ISSN: 2985-8879

Full Length Reseach Paper

Geospatial Semester: Developing Students' 21st Century Thinking Skills with GIS: A Three Year Study

Michael T. Charles[1*] and Robert A. Kolvoord[2]

[1]College of Education, Pacific University, Oregon, USA.
[2]Integrated Science and Technology, James Madison University, USA.

Accepted 24th December, 2016

Abstract

Do high school seniors who complete a community-based GIS project demonstrate evidence of recognized 21st Century thinking skills when assessed by GIS capable faculty? Projects were completed in a semester-long high school course in which students used geospatial tools daily. 21st Century Skills were defined using two prominent frameworks and applied to create a topic-specific analytic rubric. Three raters used the rubric to evaluate 138 final projects in three academic years. Analysis of the findings indicates evidence of 21st Century thinking skills. Further work suggested includes a discussion of the sustainability of this curriculum innovation using GIS technologies for learning.

Keywords: Geospatial technologies, project-based learning, 21st Century skills and cognitive processes.

INTRODUCTION

Maps and geo displays are becoming ever more prominent in daily life. From GPS navigation units in cars to Google maps, people are interpreting a flood of geospatial information. However, little research has considered how this torrent of information intersects with school curricula and could impact student learning. Calls for 21st Century Thinking Skills for students implicitly include spatial thinking skills as an integral part of the desired school reform. But just what is meant by spatial thinking skills and more broadly, 21st Century Thinking Skills, and how would one measure them in today's schools where pressure to improve student achievement scores is paramount?

This study is an example of research on new geospatial tools that students may use to become "spatial citizens" and address community problems. These innovative tools can promote engaged and sustainable learning, with means of assessment that address the possibilities and challenges of advanced technologies in public school settings that provide access to all students. In this study these tools were being used on a large scale (over 2000 high school students), and this study represents a first effort to assess student thinking in that context. This is a case study of a large-scale adoption of a technology innovation (GIS) and a first look at evidence of its impact on student thinking.

This research investigates whether high school seniors who use geospatial tools on a daily basis and who complete a final community-based GIS project demonstrate consistent evidence of recognized 21st Century thinking skills when independently rated by GIS capable faculty. This research study aims to assess what Jonsson and Svingby describe as "complex competencies in a credible way" (2007, 131). The daily use of geospatial tools and real world problem-based and community-based project-based work by the students permits the investigators to explore how these spatial tools impact learning.

The Geospatial Semester (GSS) is a unique dual-

Corresponding author email: charlesm@pacificu.edu

enrollment program in which high school seniors engage in a semester- or year-long course in which they learn to use geospatial technologies and apply them to local, community-based projects. Students can earn dual enrollment credit (at a greatly reduced tuition rate) from a local university for their work. GSS has served more than 3,000 students in the past eleven years. The class is taught by local high school teachers in multiple school districts with project mentoring and technical support via regular visits and online support from higher education faculty.

Theoretical Perspectives

This study is shaped by three important theoretical perspectives: the definition of 21st Century Skills, how such skills could be assessed in a performance-based manner applicable in K-12 classrooms, and the value of geospatial thinking in K-12 classrooms.

Defining 21st Century Skills

This study examines 21st Century Thinking Skills that have been previously identified by others. The 21st Century Workforce Commission's National Alliance of Business (2000) stated that "The current and future health of America's 21st century economy depends directly on how broadly and deeply Americans reach a new level of literacy—21st Century Literacy" (US Department of Labor, 2000). The Partnership for 21st Century Skills and the enGauge 21st Century Skills (2003) are two projects that have undertaken significant efforts to define 21st Century Thinking Skills in the past decade. The Assessment and Teaching of 21st Century Skills Project launched in 2009 was constructed to "provide data from which developmental learning progressions for students engaged in these 21st Century Skills could be constructed" (Griffin; Care; McGaw, 2012, 1). Others challenge schools to be transformed in ways that will enable students to acquire the sophisticated thinking, flexible problem solving, collaboration and communication skills they will need to be successful in work and life" (Binkley *et al.,* 2012, 18). The developers of enGauge note the fundamental dilemma that educators face: "communities expect their graduates to be ready to thrive in the Digital Age, but the 21st Century skills such success requires are not well defined. Nor are those skills included in many state learning standards or measured on most state and local assessments" (Lemke 2003, 2).

The enGauge 21st Century Skills were developed through a process that included an extensive review of literature and incorporated feedback from constituent groups (Lemke, 2003, 14). Then they described what each skill would look like in practice in the enGauge 21st Century Skills Continua of Progress "to provide teachers with explicit criteria by which to gauge students' progress" (2003, 1). The Partnership for 21st Century Skills (2004) or P21 is "a national organization that advocates for 21st century readiness for every student." It provides "tools and resources to help the U.S. education system keep up by fusing the three Rs and four Cs (critical thinking and problem solving, communication, collaboration, and creativity and innovation)." These two sources (P21 and enGauge) were used to define 21st Century Skills in this study as further described in the Methods section below.

Assessing 21st Century Skills

21st Century Skills can be assessed in a performance-based manner that is applicable in K-12 teaching settings. This can be accomplished through evidence-centered design that links 21st century skills to task features and reports of evidence that characterize student performance and progress (Scardamalia *et al.,* 2012). The developers of the assessment and teaching of twenty-first century skills project "provide a framework that can be used as a model for developing large scale assessments of twenty-first century skills" (Binkley et al. 2012, 33). Scoring rubrics are frequently used in making performance-based assessments. An educational rubric is "a scoring tool for qualitative rating of authentic or complex student work" (Jonsson and Svingby, 2007, 131). Typically a rubric is a simple assessment tool that describes levels of performance on a particular task and is used to assess outcomes in a variety of performance-based contexts from kindergarten through college (K-16) education (Hafner & Hafner, 2003, 1509). Jonsson and Svingby (2007) note that rubrics are used as part of a new assessment culture that aims at assessing higher order thinking processes and competencies instead of factual knowledge (131).

Jonsson and Svingby's (2007) review of 75 peer-reviewed studies that used rubrics in some form suggested that they can enhance the reliable scoring of performance assessment, especially if the rubric used is analytic in nature, topic-specific, and supported with exemplars or anchor papers and rater training using those exemplars (130). Jonsson and Svingby distinguish between analytic rubrics, in which a rater assigns a score to each of the dimensions being assessed in the task, and holistic rubrics in which the rater assigns a single score to the whole project. Rubrics that are specific to the topic of the assessment were found to be superior to those that are generic (Marzano 2002). Rubrics can provide for increased consistency of judgment when assessing performance and authentic tasks across students, assignments, and raters (Jonsson and Svingby 2007, 131). The rubric created for this study was influenced by our familiarity with the OPEN Scoring Guide (2004) developed by Oregon Department of Education's Office of Assessment and Evaluation.

The OPEN Scoring guide is analytic, topic-specific, and supported with exemplars that include expert comments written by state mathematics leaders and was used to assess student work in the state of Oregon from 2000-2005. It has been revised for the 2011-2012 academic year and following (ODE 2011-2012) and is once again being used to assess student progress in Mathematics Problem Solving by students across the state.

Geospatial thinking in K-12 classrooms

Spatial thinking is an ability to visualize and interpret location, distance, direction, relationships, movement and change over space (Sinton, 2009). Hence it is useful far beyond geography. Students' ability to think spatially impacts them in their everyday lives in the way they interact with the world around them--"thinking in space". They also "think about space" as they do schoolwork that involves models of the Earth, maps or other spatial displays, and as they move to higher grades (National Research Council 2006).

The critical role for a tool like GIS is in thinking about space. Students must be able to judge variation in space, how the properties of nearby objects affect each other (and distant objects), and the impact of direction (National Research Council 2006, Sinton 2009). For example, students can assess the impact of climate on local weather or to evaluate the degree of risk their location has from various natural disasters, such as hurricanes, tornadoes or earthquakes. It has been recently noted that "advanced GIS technologies afford emergent and ill-defined learning activities in which students and teachers can learn new content collaboratively (Doering *et al.,* 2014, 224). Despite the stated importance of thinking globally and understanding the Earth and its systems, geography and earth science experience little privilege in today's K-12 curriculum. However, the advent of geobrowsers (e.g. Google Earth) and geographic information system software (e.g. ArcGIS or MyWorld) has spread the opportunity to think and analyze about space across the curriculum. Numerous studies conducted over the past 50 years suggest that spatial thinking is central to success in the so-called STEM disciplines--Science, Technology, Engineering, and Mathematics (Newcomb 2010, 29).

These geospatial tools are becoming more and more prevalent in the workplace. The spatial thinking skills developed in addition to the software skills will help students work in a variety of fields from public safety to natural resources management to business site selection. Geospatial technologies are predicted by the United States Department of Labor to be one of the top three job growth areas in the next ten to fifteen years (US Department of Labor 2000). The Geospatial Semester course described in this study is one exemplar of widely implementing a course in secondary education that develops students' geospatial skills and leads students to consider how maps might lead to important decisions in the world outside of the school.

METHODS

Student projects in the GSS course were assessed for their use of spatial thinking and analysis using a topic-specific analytic rubric developed based on the 21st Century Skills objectives (Appendix 1 and Appendix 2). This is consistent with the call for using performance-based tasks to assess 21st Century Skills (Wilson et al. 2012). The rubric was developed first from a draft created by one university faculty member based on four years of experience rating projects. Then aspects of that sample rubric were compared to the enGauge 21st Century Skills Continua of Progress and the Partnership for 21st Century Skills (Lemke, 2003) Framework definitions. Items were found in both the Continua of Progress and the P21 Framework definitions that matched the work done in the GSS projects. Once those were identified, the language was changed to fit the specific topic of GSS projects.

For example, the initial draft of the GSS project rubric rated students in the category of data gathered for their projects, whether the geospatial data were drawn from professional sources or were created by the student in the form of field data, digitized data, or by geo-referencing historical maps. This aligned well with the P21 framework item "uses information accurately and creatively for the issue or problem at hand." Thus in the final rubric the descriptor used was Data Generated or Mined: The student acquires geospatial data from professional sources OR creates geospatial data (e.g. field data, digitized data, geo-referencing historical maps…).

In a second example, the enGauge 21st Century Skills Continua of Progress includes a category called Analysis with a list of four different performance levels such as Novice: student lacks analytical skills. "He/she is unable to identify even the most obvious elements of the problem or work" (Lemke 2003). The draft rubric also had this analysis category, so for the GSS rubric we edited in specific geospatial skills to create an analysis category: The student is able to use geospatial technology to analyze information: classification, selection, geo-processing tools. We then described the four levels of performance by similarly modifying the enGauge 21st Century Skills Continua of Progress descriptors for novice, basic, proficient, and advanced. We limited the final GSS rubric to a single page double-sided document to assure that it was usable by classroom teachers and the higher education instructors to score the GSS projects. We believe that this tool could ultimately be useful for GSS teachers as a single assessment instrument that all teachers could opt to use in evaluating student projects.

The resulting GSS rubric (Appendix 1) assessed each project based on six different skills: quality of spatial question, authenticity of the problem, data used for the project (whether they were generated for the project or mined from other sources), the quality of the map, the level of analysis, and the quality of the presentation. In the first year four levels of performance for each of these skills were specified: advanced, proficient, developing, and novice. The language for these categories was developed through discussions with the higher education faculty who had six years of experience working with students on their final projects in the course. The rubric was not shown to the students and the results of this assessment did not impact the students' grade in the course.

Steps were taken to improve reliability of the ratings of the projects in each of the three years. In the first year, the three raters discussed their ratings for projects after visiting each site and rating the projects. In a few cases at least two of the raters discussed their rationale for their rating as they scored the same project together. In the second year this led to the development of "anchor projects." A PDF file of a project from the previous year was selected and posted to the group to be scored by the rest of the raters on a form that reported the results to a spreadsheet so that raters could see the range of responses. After two projects were scored, a ratings form was provided with the "anchor" or "correct" score for that project (as determined by the investigators and lead raters) to help improve rater agreement. After using this rubric to assess about 100 different projects the first year, a fifth level of performance "very capable" was added between proficient and advanced to provide greater specificity at the higher end of the rating scale resulting in a revised GSS project rubric (Appendix 2). This was the rubric used in years two and three.

RESULTS

Multiple raters used the GSS project rubric to rate a total of 138 different student projects across 11 different classrooms in 4 different high schools taught by 8 different teachers in 3 different school districts in suburban and rural Northern and Central Virginia over a three year period. Each of the 138 projects was rated by three people. The raters were the two higher education faculty who helped support the course and each of the high school teachers who taught the course in their respective classes. The teacher only rated projects of the students that they taught. In less than two percent of the projects the teacher was unable to provide a rating. In these cases the third rating for a project was provided by an outside rater who was a capable user of GIS software, familiar with GSS projects and who developed the GSS rubric and assisted in its administration for all three years. 53 student projects were rated in all six skills in Year One, 56 student projects were rated in all six skills in Year Two, and 29 student projects were rated in all six skills in Year Three.

Over three years 86% of the 138 projects were rated as proficient or better. As shown in Figure 1:

1). 8% of the projects were rated advanced
2). 17% of the projects were rated very capable (a rating only available in the last two years of the project and thus for only 95 of the projects)
3). 61% of the projects were rated proficient (a rating that was called "basic" in the first year)
4). 14% of the projects were rated developing
5). 0% was rated novice.

Consistent with the overall ratings of the projects decribed above, 76% of the total of 2558 ratings (from each of the 3 raters across all six categories) over the three years were advanced, very capable, or proficient. Less than one quarter were developing or novice. As shown in Figure 2:

1). 10% of the ratings were advanced
2). 15% of the ratings were very capable (a rating only available in the last two years of the project and thus for only 95 of the projects)
3). 51% of the ratings were proficient (a rating that was called "basic" in the first year)
4). 23% of the ratings were developing
5). 1% of the ratings were novice.

Based on the data in these two figures, there is reasonable evidence that the overwhelming majority of student work demonstrated evidence of recognized 21st Century thinking skills, with a small portion of the work rated at the developing level. The ratings of all six categories for these 138 projects was reasonably reliable across multiple raters; 92% of the ratings of each of the six skills were unanimous or by consensus. More specifically:

1). 31% of the ratings of the projects were unanimous by 3 raters
2). 61% were by consensus of 2 of 3 of the reviewers
3). 8% of the project ratings were made by the median of 3 different rating.

These data provide evidence of identifiable 21st Century Thinking Skills as high school students completed a community based project in the Geospatial Semester course. The use of an analytic rubric allows a comparative analysis across the four spatial thinking skills (spatial question, data generated or mined, quality of map generated, and spatial analysis). Ratings for each of these four skills for the 138 projects are listed in Table

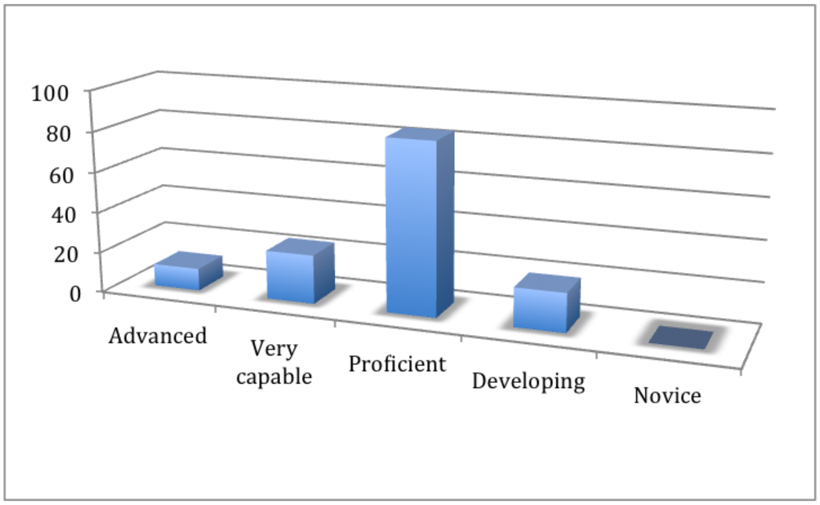

Figure 1. Overall rating of student projects

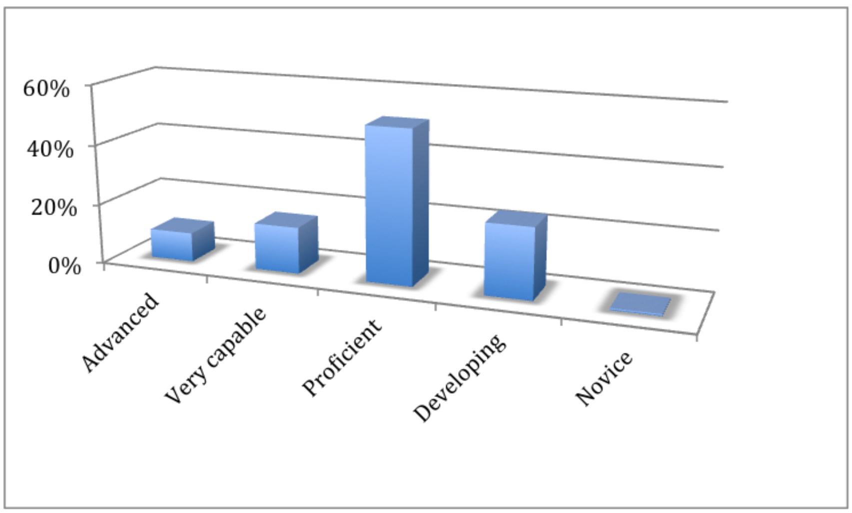

Figure 2. Distribution of the individual skill ratings from all three raters over three years

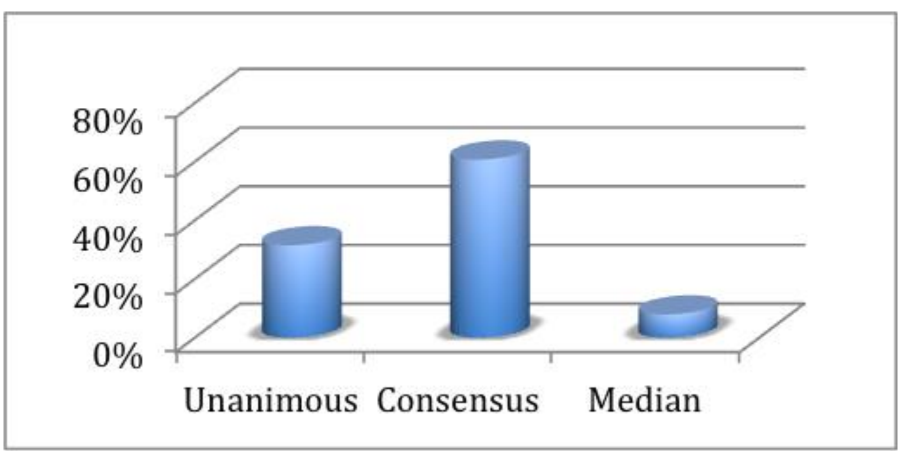

Figure 3. Reliability data for three years

	Spatial Question	Data	Map Quality	Spatial Analysis
Advanced	7%	15%	7%	7%
Very Capable	43%	31%	39%	34%
Proficient	35%	31%	36%	28%
Developing	15%	23%	18%	30%
Novice	0%	0%	0%	1%

Table 1. Ratings

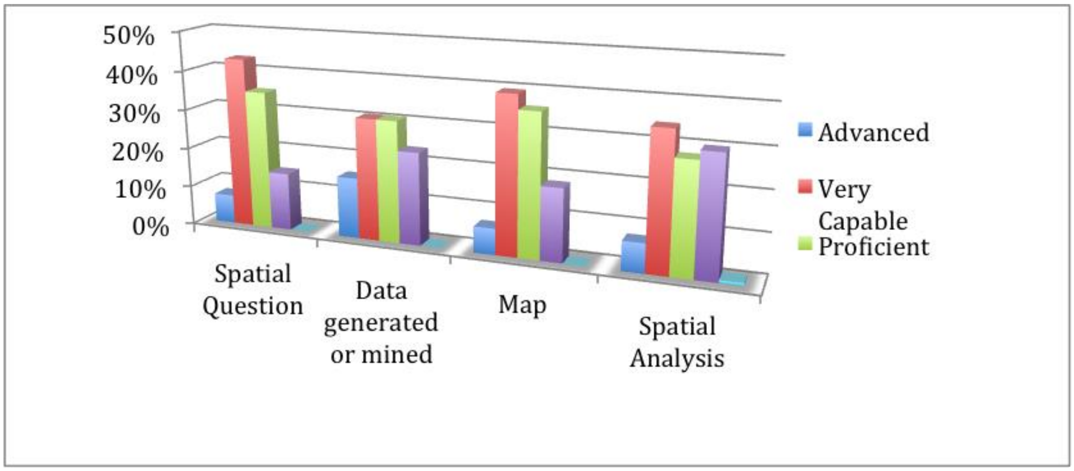

Figure 4. Comparison graph of the summative ratings in four specific spatial skills

1 and then graphed for comparison in Figure 4 in four specific spatial skills

As a whole the ratings provide evidence of proficient, very capable, and advanced thinking in the four geospatial skills. They also provide the basis for comparison. The highest percentage of advanced ratings was in the area of the quality of the data that were found or generated for the project. Overall 15% of the projects' data generated or mined were rated advanced compared to 7% for each of the other 3 categories. Thus this might be a spatial skill where students demonstrated greater mastery. However when the advanced and very capable categories are combined, there is very little difference in the ratings across each of the four spatial categories:

1). 50% of the ratings for spatial question were advanced or very capable
2). 46% of the ratings for data generated/mined were advanced or very capable
3). 46% of the ratings for map quality were advanced or very capable
4). 42% of the ratings for spatial analysis

These data suggest a second finding, which is that spatial analysis is the most challenging of the four spatial categories for students. Noting that spatial analysis is the category that has the highest percentage of developing ratings further supports this:

1). 30% of the ratings for spatial analysis were developing.
2). 18% of the ratings for map quality were developing.
3). 23% of the ratings for data mined/generated were developing
4). 15% of the ratings for spatial question were developing

In addition a lower percentage of the ratings for spatial analysis were proficient. Specifically:

1). 28% of the ratings for spatial analysis were proficient.
2). 18% of the ratings for map quality were proficient.
3). 23% of the ratings for data mined/generated were

proficient.
4). 15% of the ratings for spatial question were proficient.

This study provides evidence that framing a quality spatial question together with identifying and gathering data to answer that question and producing a cartographically correct map are easier tasks than spatial analysis (i.e. doing insightful analysis using geospatial tools). Advanced analysis involves identifying relationships and elements within a problem that are beyond teacher expectations, which is well beyond providing merely appropriate analysis using the geospatial tools. Analysis has long been noted as more challenging thinking for students (Bloom, 1956) and so it is not a surprise that the evidence in this study confirms that spatial analysis is the most challenging for students as they complete these community-based projects.

Based on preliminary findings in the second year of the study, the faculty in the Geospatial Semester course began some voluntary professional development efforts for high school teachers to help them better develop students' ability to do spatial analysis. These efforts took the form of webinars before and during the school year and involved discussion and interaction between the high school teachers and university faculty, as well as limited discussions between university faculty and students as the students pursued their projects.

LIMITATIONS OF THE STUDY

There are three clear limitations to the study. First, our initial hope was to assess about 100 projects each year, making the three year total of projects assessed more than double our final total of 138. In the three years we assessed over 300 projects, but we were not always able to have three judges rate them (e.g. in the first year we had over 40 projects that we evaluated at one site with two judges only because the classroom teacher was on maternity leave beginning that day). The other challenge we had was in getting signed permissions from the students to allow their project ratings to be included in the research data per University and District Institutional Review Board guidelines.

Second, the raters were not as independent as might be desirable. As an initial first step in evaluation, having the three faculties who collaborate with the students on the work evaluate the project is good. But a more independent evaluation by outside experts who have not worked with the students would be more persuasive evidence of recognized 21st Century thinking skills. Likewise, the high degree of inter-rater reliability is encouraging, but it is not too surprising that two university faculty and one high school science teacher who worked together with the students and who cooperatively rated some "anchor" projects so that there would be agreement on what constituted a given rating and who were able to converse informally about the projects after they had rated them would generally agree on their ratings as they do this over three years' time.

DISCUSSION

Others have presented studies of teachers implementing geospatial technologies in K-12 classrooms (MaKinster, J., Trautman, N., and Barnett, 2014). This study is an initial effort to look for evidence of 21st Century Thinking engaged in by these students and assessed in a typical high school classroom. The study points the way to further work in several areas. After the first year, the rubric was revised based on input from both the high school and higher education faculty who used it, adding the "very capable" level of performance to the rubric. With hundreds of GSS projects archived, anchor projects have been developed as exemplars of advanced, very capable, proficient, and developing levels of performance (Jonsson & Svingby 2007, 132). These anchor papers were used during the study to train others to learn to rate GSS projects in a more consistent manner as they implement the GSS Semester in their school districts, and they could have a future use in creating a common assessment protocol for all projects in the Geospatial Semester.

Foremost among concerns about the long-term ill effect of the current standardized assessment practices in K-12 schools are the ways in which the curriculum is reduced to a litany of factoids and students are poorly prepared for a changing world. The GSS course is based on performance-based assessment. It employs the regular use of a professional GIS tool culminating in the completion of a community-based project. The course is supported and evaluated by both high school and higher education faculty, providing a higher level of quality control of the course content than is typical in high school dual enrollment offerings. It is sustainable because the dual enrollment aspect provides a revenue stream for the university in the form of discounted tuition payments, allowing the assignment of faculty time. The provision of dual enrollment credit also serves as a good recruiting tool to promote student and parental interest. Mentored dual enrollment courses such as the Geospatial Semester offer secondary students the possibility for a different sort of rigor and bear further investigation.

This study supports the notion that one can create an assessment tool that can be used in the field to provide evidence of 21st Century thinking and for teacher reflection. This study provides tangible evidence that the GSS course supports the development of the kind of 21st Century thinking skills that many believe are vital as today's students prepare to face to tomorrow's problems. Having used this low cost assessment tool with relative success with students, we note the inadequacy of the projects at capturing all the learning in a course such as GSS. The students also develop substantial skill in the use of geospatial technologies, including GIS software and GPS units. They develop their spatial thinking skills through a number of smaller-scale projects throughout the year. While the rubric-based assessment of the final projects captures some of this learning, it does not span the full sweep of the complete course.

ACKNOWLEDGMENTS

This research was supported in part by a Visionary Grant from The Scripps Research Institute's Visualization in Science and Education project, funded by the National Science Foundation.

REFERENCES

Binkley, M., Erstad, O., and J. Herman (2012) Defining Twenty-First Century Skills. In Assessment and teaching of 21st century skills, ed. P. Griffin, B. McGaw, and E. Care, pp.17-66. New York: Springer.

Bloom B. S. (1956). Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain. New York: David McKay Co Inc.

Doering, A., Koseoglu, S., Scharber, C., Henrickson, J., and Lanegran, D. (2014). "Technology Integration in K–12 Geography Education Using TPACK as a Conceptual Model." Journal Of Geography 113, no. 6: 223-237.

Geospatial Semester (2014). http://www.isat.jmu.edu/geospatialsemester

Griffin, P., Care, E. and B. McGaw. (2012). The changing role of education and schools. In Assessment and teaching of 21st century skills, ed. P. Griffin, B. McGaw, and E. Care, pp.1-15. New York: Springer.

Hafner, J. & Hafner, P. (2003). Quantitative analysis of the rubric as an assessment tool: an empirical study of student peer-group rating. International Journal of Science Education 25, no. 12:1509 – 1528

Jonsson A. and Svingby G. (2007). The use of scoring rubrics: Reliability, validity and educational consequences. Educational Research Review 2:130-144.

Lemke, C. (2003). enGauge 21st Century Skills: Digital literacies for a digital age. ERIC Document Reproduction Service No. ED463753.

MaKinster, J., Trautman, N., and Barnett, M. Eds. (2014), Teaching Science and Investigating Environmental Issues with Geospatial Technology. New York: Springer Publishing.

Marzano, R.J. (2002). A Comparison of selected methods of scoring classroom assessments. Applied Measurement in Education. 15, 249-267.

National Research Council. (2006). Learning to think spatially. Washington DC: National Academies Press.

OPEN Scoring Guide--Mathematics. (2004). Oregon Department of Education's Office of Assessment and Evaluation. Retrieved from http://www.openc.k12.or.us/scoring/

Oregon Department of Education (ODE): Mathematics Problem Solving Work Sample Tasks (2011-2012). http://www.ode.state.or.us/wma/teachlearn/testing/scoring/guides/2011-12/mathpsscoringguide_eng_1112.pdf

Scardamalia, M., Bransford, J., Kozma, R., and Quellmalz, E. (2012) New Assessments and Environments for Knowledge Building. In Assessment and teaching of 21st century skills, ed. P. Griffin, B. McGaw, and E. Care, pp.231-300. New York: Springer.

Sinton, D. (2009). "How can We Reap the Greatest Educational Benefits from GIS? Presentation at the 2nd National Summit on GIS in K-12 Education, Harrisonburg, VA, June 26-27. http://www.isat.jmu.edu/stem/2009%20Conf%20presentations/Sinton_presentation_JMU.pdf

The Partnership for 21st Century Skills. (2004). http://www.p21.org/.

United States Department of Labor, (2000) A Nation of Opportunity: Building America's 21st Century Workforce. 21st Century Workforce Commission-National Alliance of Business June 2000. Executive Summary, page 5. Retrieved from http://eric.ed.gov/?id=ED442971

United States Department of Labor. (2010). Retrieved from: http://www.doleta.gov/BRG/Indprof/geospatial_profile.cfm.

Wilson, M., Beja, I., Scalise, K., Templin, J., Wiliam, D., Irribarra, D. (2012). Perspectives on methodological issues. In Assessment and teaching of 21st century skills, ed. P. Griffin, B. McGaw, and E. Care (Eds.). 67-142. New York: Springer.

Appendix 1. Geospatial Semester Project Rubric used in Year 1

Spatial Question* **	**Novice**	**Developing**	**Proficient**	**Advanced**
The student poses a question with a spatial component that is based on a sound understanding of geospatial technology. (Using 21st century skills to understand and address global issues)**	The project does not have a spatial component.	The project has a spatial component that is based on a limited understanding of geospatial technology.	The project has a spatial component that is based on a sound understanding of geospatial technology.	The project has a spatial component that is based on an advanced understanding of geospatial technology.
Authentic problems* The student uses geospatial technology to identify and solve complex problems in real world contexts	Novice Student lacks expertise, and/or interest in using geospatial technology to solve complex, authentic problems.	Developing Student applies geospatial technology to complex, authentic problems only with significant support and direction from the teacher. Products created are fairly traditional.	Proficient Student applies geospatial technology to complex, authentic problems with minimal support and direction from the teacher, occasionally creating products that have real value to audiences outside of the classroom.	Advanced Student applies technology to complex, authentic problems independently, often creating products that have real value to audiences outside of the classroom.
Data Generated or Mined*** The student acquires geospatial data from professional sources OR Creates geospatial data (e.g. field data, digitized data, georeferencing historical maps…) [uses information accurately and creatively for the issue or problem at hand]**	Novice Student acquires incomplete geospatial data from sources OR incorrectly creates geospatial data	Developing Student acquires limited geospatial data from sources OR creates geospatial data with some limitations	Proficient Student acquires geospatial data from professional sources OR Creates geospatial data (e.g. field data, digitized data, georeferencing historical maps…)	Advanced Student acquires particularly rich geospatial data from professional sources OR Creates particularly insightful geospatial data (e.g. field data, digitized data, georeferencing historical maps…)

Deliverables ***	Novice	Developing	Proficient	Advanced
Map?	The student's maps are not clear or do not use good cartographic design. The maps and other deliverables do not related to the spatial problem.	Some of the student maps are clear and cartographically correct, but many are not adequate or directly related to the spatial problem.	Most of the student maps are clear and cartographically correct, but some have substantial errors or are not adequate or directly related to the spatial problem.	The student develops clear and cartographically correct maps that describes their spatial analysis. All maps and deliverables directly related to the spatial problem at hand.
Analysis*	Novice	Developing	Proficient	Advanced
The student is able to use geospatial technology to analyze information • Classification • Selection • Geoprocessing Tools	Student lacks analytical skills with geospatial tools.	Student can conduct simple analysis using geospatial tools with assistance.	Student can provide appropriate analysis using geospatial tools of the problem.	Student provides thoughtful and insightful analysis using geospatial tools, often identifying relationships and elements within a problem that are beyond expectations.
Presenting*	Novice	Developing	Proficient	Advanced
The student presents information clearly and accurately	Student is unable to present information accurately, concisely, or clearly.	Student is able to present information somewhat accurately, but the presentation is neither clear nor compelling.	Student is able to present information accurately and efficiently, but the presentation is not entirely compelling.	Student is able to present information accurately, efficiently, and in a compelling manner.

Sources: *enGauge 21st Century Skills Continua of Progress, **P21 Framework definitions, ***faculty rubric draft
Deliverables ratings from Prioritizing, Planning, and Managing for Results involve the ability to organize to achieve the goals of a specific project or problem efficiently and effectively (enGauge

Appendix 2. Revised Geospatial Semester Project Rubric used in Year 2

Spatial Question* **	**Novice**	**Developing**	**Proficient**	**Very capable**	**Advanced**
The student poses a question with a spatial component that is based on a sound understanding of geospatial technology.	The project does not have a spatial component.	The project has a spatial component that is based on a limited understanding of geospatial technology.	The project has a spatial component that is based on a sound understanding of geospatial technology.	The project has a spatial component that is based on an advanced understanding of geospatial technology.	The project has a spatial component that is based on an advanced understanding of geospatial technology and is a sophisticated application
Authentic problems*	Novice	Developing	Proficient	Very capable	Advanced
The student uses geospatial technology to identify and solve complex problems in real world contexts	Student lacks expertise, and/or interest in using geospatial technology to solve complex, authentic problems. No or few products created.	Student applies geospatial technology to complex, authentic problems only with significant support and direction from the teacher. Products created are fairly traditional.	Student applies geospatial technology to complex, authentic problems with minimal support and direction from the teacher. Products created are fairly traditional.	Student applies geospatial technology to complex, authentic problems independently, occasionally creating products that have real value to audiences outside of the classroom.	Student applies geospatial technology to complex, authentic problems independently, regularly creating products that have real value to audiences outside of the classroom.
Data Generated or Mined***	Novice	Developing	Proficient	Very capable	Advanced
The student acquires geospatial data from professional sources OR Creates geospatial data (e.g. field data, digitized data, georeferencing historical maps…)	Student acquires incomplete geospatial data from sources OR incorrectly creates geospatial data	Student acquires limited geospatial data from sources OR creates geospatial data with some limitations	Student acquires geospatial data from professional sources OR Creates geospatial data (e.g. field data, digitized data, georeferencing historical maps…)	Student acquires appropriate geospatial data from a variety of sources OR Creates geospatial data (e.g. field data, digitized data, georeferencing historical maps…) that is appropriately documented (metadata)	Student acquires appropriate and particularly rich geospatial data from professional sources OR Creates particularly insightful geospatial data (e.g. field data, digitized data, georeferencing historical maps…) that is appropriately documented (metadata)

Deliverables * **	**Novice**	**Developing**	**Proficient**	**Very capable**	**Advanced**
Map	The student's maps are not clear or do not use good cartographic design. The maps and other deliverables do not relate to the spatial problem.	Some of the student maps are clear and cartographically correct, but many are not adequate or directly related to the spatial problem.	Most of the student maps are clear and cartographically correct, but some may not be adequate or directly related to the spatial problem.	Most of the student maps are clear and cartographically correct, but there may be a few errors or displays not directly related to the spatial problem.	All of the student maps are clear and cartographically correct and describe their spatial analysis. All maps and deliverables are directly related to the spatial problem at hand.
Analysis*	Novice	Developing	Proficient	Very capable	Advanced
The student is able to use geospatial technology to analyze information • Classification • Selection • Geoprocessing Tools	Student lacks analytical skills with geospatial tools.	Student can conduct simple analysis using geospatial tools with assistance.	Student can provide appropriate analysis using geospatial tools of the problem.	Student can provide some more thoughtful and insightful analysis, but their overall analysis has some limitations or could have been extended.	Student provides thoughtful and insightful analysis using geospatial tools, often identifying relationships and elements within a problem that are beyond expectations.
Presenting*	Novice	Developing	Proficient	Very capable	Advanced
The student presents information clearly and accurately	Student is unable to present information accurately, concisely, or clearly.	Student is able to present information somewhat accurately, but the presentation is neither clear nor compelling.	Student is able to present information accurately and concisely, but the presentation is not entirely compelling.	Student is able to present information accurately, concisely, and in a compelling manner, but with some errors or limitations.	Student is able to present information accurately, concisely, and in a compelling manner.