AC 2012-3851: TRANSFORMING A CIVIL ENGINEERING CURRICULUM THROUGH GIS INTEGRATION

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Charles V. Camp has been involved with developing and teaching the foundation sequence in the Department of Civil Engineering for the past 15 years. The foundation sequence provides active learning environment in which students develop knowledge and understanding of civil engineering through team-based design projects focusing on application, analysis, and evaluation of design alternatives. Camp received the Thomas W. Briggs Foundation’s "Excellence in Teaching Award" in 2002 and Herff College of Engineering "Teacher of Year" Award in 2000. Camp is a co-author of several Best Research Paper awards for innovative engineering education, most recently the 2008 Best Conference Paper as ASEE Southeastern Section. In addition, Camp is active in research and has more than 50 journal and conference paper publications and has been involved in numerous funded research projects over the last 20 years.

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Transforming a Civil Engineering Curriculum
Through GIS Integration

Introduction
The role of Civil Engineers is evolving beyond that of a technical professional with recognition that civil engineers play a critical role in the planning, management, and development of the infrastructure of a community. One critical element of Civil Engineering, as demonstrated by recent reports developed by the American Society of Civil Engineers and the National Academy of Engineering, is the ability to visualize the impact that design decisions will have not only on the technical aspects but also on economic, social, environmental, and political consequences. Geographic information systems (GIS) enable users to visualize some of these factors and as such are becoming a critical tool for the Civil Engineering design professional.

In recognition of this trend, University of Memphis Civil Engineering faculty are undertaking a collaborative three-year curriculum transformation project to integrate a GIS-enabled design approach across a sequence of required Civil Engineering courses at the 1000, 2000, and 3000 course levels. The curriculum will be both sequenced and scaffolded (designed to provide support structure to facilitate learning of new skills) across six courses to ensure a clear path for student skills progression in terms of technical competency, data synthesis and analysis, and problem solving. Our goal is to develop a series of integrated, progressively challenging, and interdependent curricular materials and activities that will improve the ability of Civil Engineering students to analyze engineering problems in multiple contexts using a GIS platform.

We expect that students will demonstrate fluency with one or more of the following skills upon completion of each Civil Engineering course targeted for this project:

1. Demonstrate technical competency in fundamental GIS skills utilizing existing GIS data to examine Civil Engineering problems.
2. Analyze Civil Engineering problems by generating GIS data and integrating it with existing data while demonstrating comprehension of multiple decision factors.
3. Synthesize data acquisition and analysis within the Civil Engineering design process to develop solutions considering multiple contexts (i.e. economic, social, environmental, and political factors).

In addition to these expected, course-related cognitive outcomes, this project is expected to improve student attitudes concerning their course-based learning experiences by actively engaging them in visual-based learning processes.

This paper will document project rationale along with activities, findings, and lessons learned from our first project year. The major activities to date include the refinement of a set of skill development objectives for the project by year of implementation, development of a formal evaluation plan, development and implementation of curriculum for freshman courses targeted by the project, development of a web resource for project transferability, and assessment of Year 1 data.
Project Background/Rationale

Driving Factors
Technological knowledge, skills, and applications are important contributors to the professional success of all students. For engineering students, however, these skills and applications strategies are critical components required for professional practice in the 21st century. In response, engineering educators face instructional challenges related to teaching the core content of traditional engineering practice while integrating the ever-changing influx of technological tools and applications. Additional challenges revolve around the delicate balance that must be maintained between educating and graduating engineering students who are suitably prepared for professional practice in engineering fields without adding credit hours to undergraduate program requirements.

Recent changes in the Accreditation Board for Engineering and Technology (ABET) criteria for Civil Engineering graduates require that students be able to address Civil Engineering problems in terms of global and societal context. New outcomes include educating students who are aware of contemporary issues and capable of effectively using modern engineering tools. These new requirements reflect the changing role of the Civil Engineer in society, and ABET's recognition that stakeholder expectations must also be a focus in the education of new Civil Engineers. Similarly, the National Academy of Engineering (NAE) recommends that curriculum changes be combined with changes in teaching strategy to ensure that students are equipped with more than just traditional technical knowledge and prepared to meet the challenges of the future. In addition, the American Society of Civil Engineers (ASCE) updated the skills criteria for the 21st century engineer (Body of Knowledge - BOK), with the second edition (BOK2) outlining twenty-four outcomes that civil engineers should achieve and linking cognitive achievement levels to points within the civil engineer’s education/career. In the BOK2, Bloom’s Taxonomy is used to define cognitive levels, with achievement at the low-mid range of the scale (levels 1-Knowledge, 2-Comprehension, and 3-Application) designated as an appropriate level for the bachelor’s degree for most outcomes. However, students graduating with a bachelor’s degree are expected to achieve level 4 (Analysis) for mechanics, experiments, design, breadth in civil engineering areas, communication, and professional and ethical responsibility and level 5 (Synthesis) for design.

The University of Memphis (UM) is a learner-centered metropolitan research university committed to providing high quality educational experiences while pursuing new knowledge through research, artistic expression, and interdisciplinary and engaged scholarship. The UM Department of Civil Engineering currently has 10 full-time faculty members serving 109 undergraduate students and 40 graduate students. A team of three Civil Engineering faculty developed the concept for this project in response to the changes imposed by ABET as outlined above, in addition to stakeholder feedback and a desire to address retention issues in the department, particularly related to our female and underrepresented student populations. Constituent feedback from alumni and employers of UM graduates indicates the need for increased competency of our graduates in GIS or other visualization software, improved decision-making abilities, and increased ‘real-world’ applications incorporated into the curriculum. In a recent survey of department graduates, the importance of the ability to understand the impact of engineering solutions in a global and societal context was rated as...
either critical or necessary by 82% of the respondents, yet only 38% of the graduates responded that they were well prepared to address global and societal contexts in engineering when they graduated.

Data collected since 2005 indicates rates of attrition in the UM Department of Civil Engineering are approximately 50%\(^5\), a trend also observed nationally\(^6,7,8\). The average rate of attrition of female students from the UM Civil Engineering program is 60%, with the percentage of female students graduating from the program hovering around 15% for the past 4 years\(^5\). Nationally, female students represent slightly less than 15% of Civil Engineering graduates, with attrition rates slightly higher than that for males\(^6,9,10\). Minority students make up only 14% of the Civil Engineering students at the UM, with attrition rates hovering around 69%\(^5\). Higher attrition rates of these students are an issue nationwide with underrepresented minority students receiving roughly 10% of all engineering degrees\(^6,9,10,11\). Research consistently shows that students, and in particular female and minority students, respond favorably to connections between technical content and global/societal contexts in an active learning environment and are more likely to be retained in programs using these approaches\(^10,12,13\), thus influencing the decision to pursue integration of projects highlighting these aspects.

Research regarding Civil Engineering student learning styles has been conducted at the UM since 2005, incorporating two learning style assessment instruments. Results indicate that students have a strong preference for visual and active learning. The Kolb Learning Style Instrument\(^14\) and the Felder Index of Learning Styles\(^15,16\) have been distributed to all entering freshman in the program during each of the past six years. These instruments indicate that 97% of the students prefer visual versus verbal learning, and that more than 70% have a preference for hands-on active learning experiences. National research also indicates this preference and demonstrates the effectiveness of visualization tools for student learning\(^17-21\).

GIS for Visualization
This project melds the visualization tools provided by GIS with an active learning environment. The utilization of the active learning process, in particular problem-based learning is supported by a body of research indicating students develop deeper understanding of concepts and retain more of what they learn with these pedagogical approaches\(^22-26\). Visualization as a critical learning skill in the understanding of technical material has been widely studied. The National Science Foundation (NSF) has recognized the critical role that visualization plays through their International Science and Engineering Visualization Challenge, the synopsis for which states “In a world where science literacy is dismayingly rare, illustrations provide the most immediate and influential connection between scientists and other citizens, and the best hope for nurturing popular interest. Indeed, they are now a necessity for public understanding of research developments”\(^27\).

GIS is recognized as an essential tool used widely in the Civil Engineering profession, but academia has been slow to recognize GIS skills as an essential tool for Civil Engineering graduates\(^17,28,29\). GIS has become an engineering standard for developing, analyzing, managing, and displaying geographic information. In Civil Engineering, GIS has become vital to the success of projects in many areas including surveying, site development, hydraulics, hydrology, transportation, planning, and public works. In particular, GIS provides a unique combination of
complex relational databases, comprehensive spatial analysis tools, and powerful 2D and 3D graphical displays that allow engineers to better manage information for design and modeling. For these reasons, we selected GIS as the tool for this curriculum transformation project. We use ESRI’s ArcGIS software for the implementation of the course projects. We selected this system because it is widely used and many universities, including the UM have site licenses for the software, facilitating its use by faculty and students.

Similar GIS curricular development at the Missouri University of Science and Technology (MUST) at Rolla developed a prototype computer-based-learning system designed to introduce students and faculty to GIS. The initial stage of the project involved development of a module for a single course. A follow-up to this project further develops five modules for use in Civil Engineering curriculum. The goal of the MUST project is the development of the web-based system and analysis of how students learn from such systems. The modules developed from the MUST project are intended to be used in foundation courses in Civil Engineering curriculum, are self contained, and are intended to be used in a lab or as a homework assignment. A comprehensive problem solving strategy and GIS procedure for each module is presented allowing beginning students with little or no background in GIS to work their way through the assignment and develop a solution to the problem. Project evaluation indicates the strategy is effective for increasing students’ conceptual understanding of Civil Engineering problems as well as broader impact of design solutions.

Integration Strategy
While many Civil Engineering programs offer courses in GIS or courses that use GIS for some aspect of the curriculum, our concept is unique because we are integrating GIS as a teaching tool throughout the first three years of the Civil Engineering curriculum, beginning with first semester of freshman year. We are both sequencing and scaffolding GIS content, allowing students to increase core GIS fluency while building increasingly robust engineering skills through projects gradually increasing in complexity. Projects are integrated throughout the curriculum and are designed to build from prior projects, thus allowing students to see the links between courses rather than just providing isolated experiences. We expect that students will be able to recognize and integrate technical aspects with economic, social, environmental, and political consequences of engineering decisions utilizing a GIS as part of the engineering design process. This project builds from a pilot-scale implementation of GIS into our curriculum. The pilot project, while effective for increasing student interest and understanding of some concepts, was not achieving our ultimate goals because the projects implemented were ‘canned’ (relevant GIS skills-based projects publicly available), and were not connected well to each other or to our broader goal of demonstrating multiple contexts. From this experience, the faculty team recognized the shortcomings of the pilot project in integration, collaboration, and assessment, and formed the concept for the current project.

Project Methodology
The overarching goal is to develop and implement a series of new curricular materials and activities that will improve the ability of Civil Engineering students to analyze engineering problems in multiple contexts using a GIS platform. Our ultimate desired outcome is that students will be able to recognize and integrate both the technical aspects and the economic,
social, environmental, and political consequences of engineering decisions utilizing a GIS as part of the engineering design process. Our overall strategy is to gradually build mastery of GIS skills and increasingly sophisticated analysis capabilities related to the economic, social, environmental, and political consequences of Civil Engineering design decisions. Towards these ends, this project is integrating GIS-enabled design approaches in one required course each semester of the first three years of the Civil Engineering curriculum (six total courses) at the University of Memphis (UM).

Collaborative design is critical to the success of this project. The project team began by defining the specific desired skills and capabilities to be mastered by the end of the third year of the Civil Engineering program as set forth in our proposed learning outcomes, including both GIS skills and Civil Engineering technical content. The team then assigned specific targets for each year in terms of GIS and Civil Engineering content knowledge and application. The faculty member responsible for instruction of a particular targeted course takes the lead in designing GIS-based projects for that course; however, all team members are involved in the course project design to ensure that projects result in appropriate sequencing and scaffolding of GIS and Civil Engineering content.

Table 1 identifies the required, targeted courses for program implementation in each semester of the first through third years of the Civil Engineering curriculum as well as the targeted date of implementation and a brief course description. Faculty that comprise the project team have been responsible for instruction of these targeted courses for many years (ranging from seven to twelve years), so each team member has a significant amount of course assessment data and experience from which to work. These particular courses were selected, because the project team identified logical links and mechanisms for building skills and content knowledge between this series of courses. One to three projects using GIS as a tool for visualization and analysis are being developed for each course through this curriculum transformation project.

Specific learning objectives tied to each expected cognitive outcome are as follows:

**Year 1:** Demonstrate technical competency in fundamental GIS skills utilizing existing GIS data to examine Civil Engineering problems.

a. Define key GIS terminology
b. Identify the process required to import data into GIS software
c. Recognize two methods for making measurements within GIS
d. Manipulate data to prepare maps demonstrating solutions to simplified Civil Engineering problems using GIS software

**Year 2:** Analyze Civil Engineering problems by generating GIS data and integrating it with existing data while demonstrating comprehension of multiple decision factors.

a. Collect GIS data and import to tables, shapefiles or geodatabases
b. Edit data within GIS software
c. Identify/discuss decision factors that may play a role in the development of Civil Engineering solutions
Year 3: Synthesize data acquisition and analysis within the Civil Engineering design process to develop solutions considering multiple contexts (i.e. economic, social, environmental, and political factors).

a. Identify data required for analysis of Civil Engineering problems
b. Assemble data in GIS format
c. Develop solutions to Civil Engineering problems considering multiple factors using GIS for analysis and decision-making

After completion of the initial curriculum transformation effort, we plan to expand our team to involve faculty who teach senior-level required courses and elective courses covering topics such as water resources, applied soils, and traffic engineering, thus extending the integration of GIS across all four years and sub-specialties of the Civil Engineering curriculum. Figure 1 indicates the expected progression of cognitive achievements by academic program year. The goals for these achievements were designed to primarily reflect the ASCE BOK2 recommendations. While we recognize that Synthesis and Evaluation are high-level cognitive outcomes, and that ASCE designates level 6 (Evaluation) as being achieved beyond the bachelor’s degree for the BOK2, we believe that these levels are appropriate and achievable as narrowly defined by our learning objectives above.

Activities to Date

Curriculum Development

Curriculum for the freshman level courses (targeted freshman level course in both fall 2010 and spring 2011 semesters) was developed during the summer of 2010. All curricula was developed collaboratively by the project team, with the instructor for CIVL 1101/1112 taking the lead in team meetings and guiding the overall course project development so that projects would integrate well with course topics. Projects developed through this effort replaced other similar content (but non-GIS based) projects in the courses.

The team introduced a series of three projects in CIVL 1101, since this would be the first experience with GIS for the students, and two additional (but more complex) projects in CIVL 1112 that would build from skills taught in CIVL 1101. The CIVL 1101 and 1112 projects were designed to help students become proficient in basic GIS skills including importing data into the software, making measurements using multiple methods, and creating maps, through a project with a civil engineering context. The projects for CIVL 1101 were designed to familiarize students with the ArcGIS system and to teach basic skills including querying data, making maps, and making basic measurements. These included making basic maps of the project site that students were required to survey and using GIS to calculate materials costs based on vendor locations for a concrete mix design, using multiple tools within ESRI ArcMap. The projects for CIVL 1112 involved additional mapping, simple data analysis, and basic data editing. These included using GIS to create a spatially-referenced lighting database for the U of M campus and to prepare a map of facilities (under the context of safety analysis/planning), and to map ‘restricted areas’ for a hypothetical water treatment plant (under the context of disaster planning), creating buffers around the ‘restricted areas’ to identify potential treatment plant locations. In addition, two introductory sessions (one lecture, one lab) were also included in CIVL 1101 to introduce students to GIS, make them aware of applications where civil engineers might use GIS as a tool for problem solving and decision-making, and to introduce students to key terminology.
A set of basic help documents was also compiled and placed on the course websites to serve as a reference for students.

Table 1: Proposed Courses for Curriculum Modification

<table>
<thead>
<tr>
<th>Year</th>
<th>Course</th>
<th>Implementation Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>CIVL 1101: Civil Engineering Measurements</td>
<td>Fall 2010</td>
<td>Introduction to the Civil Engineering curriculum and profession. Students are introduced to multiple areas of Civil Engineering, including surveying, environmental, and structural topics.</td>
</tr>
<tr>
<td></td>
<td>CIVL 1112: Civil Engineering Analysis</td>
<td>Spring 2011</td>
<td>Continuation of CIVL 1101, further expands student understanding of problem solving strategies, fundamental Civil Engineering content, and Civil Engineering as a profession.</td>
</tr>
<tr>
<td></td>
<td>CIVL 2101: Civil Engineering Visualization</td>
<td>Fall 2011</td>
<td>Introduction to software typically encountered in the Civil Engineering profession and to problem solving within a visualization environment.</td>
</tr>
<tr>
<td></td>
<td>CIVL 2107 – Civil Engineering Computation</td>
<td>Spring 2012</td>
<td>Development of computational skills within Excel, Matlab, and Visual Basic.</td>
</tr>
<tr>
<td>Sophomore</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior</td>
<td>CIVL 3103: Approximations and Uncertainty in Engineering</td>
<td>Fall 2012</td>
<td>Introduction of basic probability and statistics, discrete and continuous models, statistical inference, and multiple regression.</td>
</tr>
<tr>
<td></td>
<td>CIVL 3161: Transportation Systems Engineering</td>
<td>Spring 2013</td>
<td>Introduction of fundamental concepts, design considerations, and basic evaluation/design applications for highways and intersections along with contemporary issues such as aging driver population.</td>
</tr>
</tbody>
</table>
Evaluation Plan
The evaluation plan consists of a series of evaluation questions (described in Table 2.), addressed through a mixed-methods approach that includes course Introduction/Exit surveys, skill competency assessments, student and faculty focus groups, student performance analysis (based upon project/course grades) and analysis of retention data. The student Introduction Survey is designed to investigate perceptions regarding Civil Engineering (e.g., course contents, opportunities and careers), learning approaches in Civil Engineering, and perceived outcomes of learning at the start of each project year. This is important to document baseline perceptions so that project impact can be evaluated. Upon completion of each redesigned course, students take a short Exit Survey assessing views of the course and knowledge acquired. Competency assessments (Test 1, Test 2 and Test 3) are designed to capture specific content knowledge related to GIS systems (what they are and how to integrate data) and applications in Civil Engineering for each of the 6 specified courses. Questions incorporate target knowledge expected to be acquired by project students. Beginning with CIVL 1112, each competency test contains the questions for the current course, plus those from the course immediately preceding it (for assessment of knowledge retention). All surveys are conducted via an online instrument.

Student focus groups are being conducted upon the completion of each project year (scheduled for the fall semester). Focus groups are useful for teasing out key themes associated with the
Table 2. Project Evaluation Questions and Instruments

<table>
<thead>
<tr>
<th>Evaluation Questions</th>
<th>Data Collection Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What knowledge, skills, and beliefs do students possess prior to the learning experience?</td>
<td>Student Introduction Survey</td>
</tr>
<tr>
<td>2. What new knowledge, skills, beliefs, and other attributes do students gain from their experience?</td>
<td>Competency Test 1 (at end of each course)</td>
</tr>
<tr>
<td></td>
<td>Competency Test 2 (retention after several months)</td>
</tr>
<tr>
<td></td>
<td>Competency Test 3 (retention at the start of the next academic year)</td>
</tr>
<tr>
<td></td>
<td>Class assignment and course grade data</td>
</tr>
<tr>
<td></td>
<td>Student Exit Survey</td>
</tr>
<tr>
<td></td>
<td>Student focus groups</td>
</tr>
<tr>
<td>3. How does the restructured GIS course impact retention rates among Civil Engineering majors?</td>
<td>Retention data</td>
</tr>
<tr>
<td>4. What do instructors perceive about the restructured GIS-based courses and how they impact student performance, motivation, and retention?</td>
<td>Instructor interviews/focus groups (end of each academic year)</td>
</tr>
<tr>
<td>5. How have components of the restructured GIS-based courses been amended to address assessment results/feedback?</td>
<td>Instructor interviews or focus groups (end of each academic year)</td>
</tr>
</tbody>
</table>

course content. The focus group questions will be used to determine the contexts that students will consider for Civil Engineering designs/problems (i.e. technical, environmental, social, economic, political, etc.), along with the tools they will use to effectively communicate design.

The evaluation is examining progress, performance, and retention of three student cohorts (Fall 2010, Fall 2011, Fall 2012), as compared to a baseline cohort (Fall 2009). Project evaluation is being conducted by a member of the project team with a background in the evaluation of Science, Technology, Engineering and Mathematics programs and an independent evaluation group housed at the University of Memphis. The following sections will describe the data collected and analysis for the first cohort during the Fall 2010-Spring 2011 academic year.
Initial Findings

Cohort 1 Student Information
The first cohort consisted of 51 students, 35 of which responded to the Introduction Survey administered during the first week of the class, in fall 2010. The Introduction Survey, prepared by the CCLI project team, was used to collect student demographics as well as to assess student prior knowledge, skills, and beliefs related to Civil Engineering. All students were registered for the 1101 Civil Engineering class conducted in fall 2010. Of the 35 students, 3 (8.6%) were female and 32 (91.4%) were male. The majority of students were classified as freshmen - 10 (28.6%) were first-time freshmen, whereas 13 (37.1%) were freshmen who had changed majors. Most students (N = 30, 85.7%) were taking 12-15 credit hours in the fall 2010 semester.

In addition to demographic data, we obtained feedback from students about their perceived competency associated with embarking on a Civil Engineering degree. Most students (N = 29, 82.8%) believed they were well prepared or adequately prepared to start their Civil Engineering course. Based on a rating scale between 1 and 5 (1 indicating very weak and 5 indicating very strong), students rated themselves as strong in math (average rating = 4.06), average to strong in English (average rating = 3.57) and physics (average rating = 3.37), but weak to average in chemistry (average rating = 2.89). Using the same 1-5 rating scale, students also rated themselves as average to strong on a number of characteristics associated with being a successful civil engineer (creativity: 4.14; organization: 3.63; writing: 3.44; communicating: 3.94; problem-solving: 4.0; collection/analysis of data: 3.69; visualization: 3.74; and leadership: 3.91).

First Year Evaluation
This section reports data relating to the evaluation questions outlined in the previous section. The questions presented below are slightly rearranged from how they were presented in the evaluation plan to separate measures of student perceptions and beliefs versus knowledge and skills. Details regarding “missing” data are reported in the appropriate subsections, below.

**Question 1:** What beliefs do students possess about Civil Engineering prior to the learning experience? What new beliefs do students gain about Civil Engineering from their experience?

There was little difference in students’ main interest in Civil Engineering. In both the Introduction Survey and Exit Survey, students indicated they were most interested in structural aspects of Civil Engineering (as opposed to environmental engineering, geotechnical engineering, transportation engineering and water resource engineering).

There was some variation between expressed styles of learning between the Introduction and Exit Survey. While hands-on experimental methods were reported to be most popular at both times of testing, the proportion of students expressing preference for group-based/collaborative learning was higher when completing the Exit Survey (58%) than the Introduction Survey (44%). Interestingly, more students expressed preference for lectures and visual learning when completing the Introduction Survey than the Exit Survey, as shown in Table 3.
Table 3: Styles of Learning Students Enjoy

<table>
<thead>
<tr>
<th>Indicate the styles of learning you enjoy the most</th>
<th>Introduction Survey N (%)</th>
<th>Exit Survey N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td>21 (61.8)</td>
<td>16 (51.6)</td>
</tr>
<tr>
<td>Hands-on experimental</td>
<td>31 (91.2)</td>
<td>29 (93.5)</td>
</tr>
<tr>
<td>Lecture</td>
<td>10 (29.4)</td>
<td>4 (12.9)</td>
</tr>
<tr>
<td>Individual assignments</td>
<td>9 (26.5)</td>
<td>10 (32.3)</td>
</tr>
<tr>
<td>Group-based/collaborative</td>
<td>15 (44.1)</td>
<td>18 (58.1)</td>
</tr>
</tbody>
</table>

Note: Valid percent used (percentages based on number of responses generated)

Students’ preference for receiving information about a problem, presenting a solution to a problem and solving Civil Engineering problems remained consistent when completing the Introduction Survey and Exit Survey. Most students like to receive and present a solution to a problem using graphical representations (as opposed to written or verbal explanations). Further, most students like to use a combination of approaches (write out a solution, create drawings and discuss problems with others) to solve Civil Engineering problems rather than one specific method (e.g., writing out a solution or discussing problems with others).

When asked to consider which aspects are important considerations for Civil Engineering problems, students’ perspectives remained relatively constant in the Introduction Survey and Exit Survey. For example, as shown in Table 4, students viewed safety as a key consideration at both times of testing. Table 4 also shows there were a few subtle shifts in perspectives. For example, a greater proportion of students thought that aesthetics of design, economics, logistics, sustainability and technical considerations were important when completing the Exit Survey.

Table 4: Perceptions of Important Considerations in Civil Engineering Problems

<table>
<thead>
<tr>
<th>Which of the following aspects do you think are important considerations in Civil Engineering problems?</th>
<th>Introduction Survey N (%)</th>
<th>Exit Survey N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetics of design</td>
<td>22 (64.7)</td>
<td>22 (70.9)</td>
</tr>
<tr>
<td>Economics</td>
<td>25 (73.5)</td>
<td>25 (80.6)</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>29 (85.3)</td>
<td>26 (83.9)</td>
</tr>
<tr>
<td>Innovative design</td>
<td>26 (76.5)</td>
<td>21 (67.7)</td>
</tr>
<tr>
<td>Logistics</td>
<td>22 (64.7)</td>
<td>23 (74.2)</td>
</tr>
<tr>
<td>Material availability</td>
<td>28 (82.3)</td>
<td>27 (87.1)</td>
</tr>
<tr>
<td>Political considerations</td>
<td>12 (35.3)</td>
<td>11 (35.5)</td>
</tr>
<tr>
<td>Public health</td>
<td>28 (82.3)</td>
<td>28 (90.3)</td>
</tr>
<tr>
<td>Safety</td>
<td>33 (97.1)</td>
<td>29 (93.5)</td>
</tr>
<tr>
<td>Social impact</td>
<td>24 (70.1)</td>
<td>23 (74.2)</td>
</tr>
<tr>
<td>Sustainability</td>
<td>23 (67.4)</td>
<td>23 (74.2)</td>
</tr>
<tr>
<td>Technical considerations</td>
<td>25 (73.5)</td>
<td>26 (83.9)</td>
</tr>
<tr>
<td>Use of state of the art technology</td>
<td>20 (58.8)</td>
<td>17 (54.8)</td>
</tr>
</tbody>
</table>

Note: Valid percent used (percentages based on number of responses generated)
Question 2: What do students learn about GIS from the modified Civil Engineering courses?

Knowledge students acquired from the modified courses was assessed via multiple methods. First, we added GIS knowledge items to the Introduction Survey and 1101 Exit Survey (outlined above) to assess knowledge acquired from the 1101 course. Whereas the Introduction Survey tapped baseline knowledge about GIS, the Exit Survey tapped changes (increases) in GIS-related knowledge. Second, the competency tests were to assess GIS knowledge acquired from the 1112 course and knowledge retained from the 1101 course. The first competency test, administered at the beginning (January 2011) of course 1112, assessed knowledge retained from the fall 2010 1101. The second competency, administered upon completion (April 2011) of course 1112, assessed knowledge acquired from the 1112 course as well as long-term retention of knowledge acquired from course 1101. The third competency, administered at the start of course 2101 (September 2011), assessed long-term retention of knowledge from courses 1101 and 1112. Students’ performance gains from the modified courses were also evaluated by reviewing and documenting assignment and course GPA attained in courses 1101 and 1112.

Finally, students’ understanding of multiple contexts and GIS was assessed via focus groups whereby students consider Civil Engineering designs/problems (i.e. technical, environmental, social, economic, political, etc.), along with the tools they will use to effectively communicate design (e.g., GIS). Using a special focus group interview design technique developed by CREP at UM, students answered questions associated with constructing a new interstate through West Tennessee that will cross the Mississippi River. Student focus groups are conducted during the fall semester, after the completion of each project year. Baseline data for 2009-2010 students (controls) who participated in unmodified versions of courses 1101 and 1112 in fall 2009 and spring 2010, respectively were collected in Fall 2010, and data for Cohort 1 was collected in F2011. Analysis of the data is not yet available, but baseline responses will be compared to that for each project cohort to assess project impact.

In terms of the results, the Introduction and 1101 Exit surveys suggested students acquired knowledge about GIS upon completing course 1101. In the Introduction survey 12 (36.4%) of the 33 respondents who answered the question correctly, indicated that GIS stands for Geographic Information Systems. In the Exit Survey 23 (74.2%) of the 31 students who answered the question indicated that GIS stands for Geographic Information Systems, indicating a marked increase in students’ knowledge of GIS. With regard to the question, “How is GIS used in engineering?”, only 22% of 33 respondents correctly addressed this item in the Introduction survey, while 87% of 31 respondents correctly answered the question in the Exit Survey. These two questions were the only items replicated from the Introduction and Exit surveys on the competency tests.

In terms of knowledge retention, Table 5 shows student knowledge of GIS-items covered in the 1101 course was high when tested using competency test 1 (administered in January 2011), but decreased slightly when tested using competency test 2, after a delayed time interval, in April 2011. Interestingly, although the proportion of correct responses to the 1112 GIS items was high when assessed upon immediate completion of the course (April 2011), the percentage of correct
Table 5: Knowledge pertaining to items covered in courses 1101 and 1112

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Course 1101 items</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What does GIS stand for?</td>
<td>20 (84)</td>
<td>21 (77)</td>
<td>20 (84)</td>
</tr>
<tr>
<td>Name three ways a civil engineer might use a GIS.</td>
<td>20 (83)</td>
<td>21 (78)</td>
<td>20 (84)</td>
</tr>
<tr>
<td>List two ways distances can be measured in ArcMap.</td>
<td>15 (62)</td>
<td>14 (53)</td>
<td>10 (42)</td>
</tr>
<tr>
<td>Course 1112 items</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which of the following ArcGIS functions can be used to define an area within a specified distance around a feature as shown in the figure below? (images and answer choices provided)</td>
<td>NA</td>
<td>22 (81)</td>
<td>22 (92)</td>
</tr>
<tr>
<td>Which of the following ArcGIS functions can be used to define a new output coverage by overlaying two sets of features as shown in the figure below? (images and answer choices provided)</td>
<td>NA</td>
<td>17 (63)</td>
<td>18 (75)</td>
</tr>
<tr>
<td>Which of the following ArcGIS functions can be used to define a new coverage by overlaying two polygon coverages as shown in the figure below? (images and answer choices provided)</td>
<td>NA</td>
<td>20 (74)</td>
<td>22 (92)</td>
</tr>
</tbody>
</table>

NA indicates skill not introduced in CIVL 1101.
responses actually increased with competency test 3 (September 2011), which was administered before the GIS projects were implemented in 2101.

To further assess project efficacy, the overall class grades for courses 1101 and 1112 were compared to those attained by Civil Engineering students taking the unmodified 1101 and 1112 courses in the 2009-10 academic year. For both the project year and the comparison year, students achieved identical average GPAs in both 1101 (2.24) and 1112 (2.05). Average GPA scores in these courses are typically low due to this being the students’ first introduction to civil engineering (and college), and students typically struggle to adjust to expectations initially. Data will continue to be collected and compared over the entire project to determine if any improvements occur over the project period.

**Question 3: How does the restructured GIS course impact retention rates among Civil Engineering majors?**

We are conducting annual retention analysis, with retention for Civil Engineering cohorts monitored each fall. For example, for the first cohort of civil students, commencing the redesigned course program in fall 2010, retention data will be obtained at 3 critical time points – fall 2011, fall 2012, and fall 2013. Retention is classified as retention in Civil Engineering. Students who switch to a different major (even within engineering) are not classified as being retained. Thus far, no significant difference in retention statistics is discernible, with retention after one year (measured at beginning of fall semester of second year) of approximately 50% for both the baseline students and cohort 1. This is not unexpected, as it is early in the project implementation process.

**Questions 4 and 5: What do instructors feel about the restructured GIS-based courses and how they impact student performance, motivation, and retention? How have components of the restructured GIS-based courses been amended to address assessment results/feedback?**

Perspectives generated by course instructors will be captured in focus groups, along with documentation of project amendments. However, course instructor focus groups were not conducted during Year 1 as there was only one course instructor implementing projects. During years 2 and 3, there will be two and three instructors, respectively (thus, meriting the use of focus groups).

Lessons Learned

The convergence of data indicate that there were some subtle perception shifts in preferred styles of learning, but the most marked changes occurred in knowledge about GIS and promising retention of knowledge over time. There are no discernable differences in GPA or retention of project students as compared to baseline students thus far. However, this is not unexpected given only one year of data. Comparisons of focus group data will reveal whether or not differences exist in students’ abilities to recognize multiple contexts within a Civil Engineering problem between baseline and project students. As additional data is gathered with the progression of the project, more refined analysis will take place to investigate retention among subpopulations (gender and ethnic differences) and to link attitudes about learning to broader implications.
Informal discussions between project faculty and students reveals that while GIS and the ability to visualize Civil Engineering problems are of interest, the learning curve for the software is not nearly as steep as the faculty team originally expected. Students catch on quickly, and projects that were initially thought by faculty to be challenging in terms of the GIS applications have proven to be easy for students to master. Thus, changes are currently underway to increase the pace of the GIS skills introduced in each course to maintain student interest. Students also indicated that they would prefer to experience GIS throughout the semester rather than at isolated points within the course, thus we are also increasing the number of projects to three for each course in order to increase continuity.

Several changes have also been made regarding how the curriculum transformation was initially conceived. First, the team originally planned to use data available from the UM Center for Partnerships in GIS for this project. As the team began discussing the potential transferability of the project materials and concept, we instead decided to obtain the bulk of the data that will be used for our project courses from free online resources. By using freely available data for our project curriculum, this will enable us to make a much more significant impact in terms of the potential for others to replicate our work in their own settings. Thus, an additional activity that took place during the summer of 2010 was a comprehensive search and compilation of a list of online resources where data pertinent to Civil Engineering problems are available for free download.

Second, the team decided that developing an online data repository would be of significant benefit to project transferability. We are in the process of downloading a wide range of GIS data that can be used in a Civil Engineering context, categorizing the data by type (transportation, water resources, environmental, demographic, etc.), preparing a brief description of the dataset, processing it into Shelby County and Tennessee segments, and then posting the processed data on the project website. We are also including links to the full datasets on the original source website and instructions for how to process data in a similar fashion for other counties/states. At the end of the three-year project (summer 2013), a website will be available that includes all curriculum developed along with the GIS data repository so that anyone that wishes to implement the curriculum in another Civil Engineering program will have all of the resources necessary to do so.

Ongoing assessment and revision of course projects continues to take place, with implementation of sophomore level projects currently under way. Junior level projects will be developed in the summer of 2012. In addition, the freshman year projects are currently being revised for use in a summer outreach program for high school students as well. Finally, faculty development workshops will be presented at the conclusion of the project to make other department faculty aware of the project resources available, to increase familiarity and competence with ArcGIS software, and to make faculty aware of other GIS skill development resources available on campus and online.

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REFERENCES CITED