AC 2010-896: STUDENT-CENTERED EVALUATION OF A GIS LABORATORY IN TRANSPORTATION ENGINEERING

Ghulam Bham, Missouri University of Science and Technology

Dr. Ghulam Bham is an Assistant Professor of Civil Engineering at the Missouri University of Science & Technology. He received his PhD from the University of Illinois at Urbana-Champaign in 2003. His research interests include modeling and simulation of driver behavior in transportation systems, traffic operations and control, and traffic safety.

Dan Cernusca, Missouri University of Science and Technology

Dr. Dan Cernusca is Instructional Design Specialist in the Department of Global Learning at the Missouri University of Science and Technology. He received his Ph.D. degree in Information Science and Learning Technologies in 2007 from University of Missouri – Columbia. He also holds a BS and a Ph.D. from the University of Sibiu, Romania with a specialization in manufacturing technologies and respectively cutting-tools design. His research interests include Design-Based Research in technology-enabled learning contexts, technology-mediated problem solving, assessment in technology rich learning environments, applications of dynamic modeling for learning of complex topics, and the impact of epistemic beliefs on learning with technology.

Uday Manepalli, Missouri University of Science and Technology

Uday R R Manepalli is a graduate student of Civil Engineering at the Missouri University of Science and Technology. His research interests are GIS applications in civil engineering especially traffic safety with emphasis on statistical analysis of crash data and identification of high crash locations.

Ronaldo Luna, Missouri University of Science and Technology

Dr. Ronaldo Luna is an associate professor of Civil Engineering at the Missouri S&T, Rolla. He received his PhD from the Georgia Institute of Technology in 1995. His research interests include: engineering education, geotechnical and earthquake engineering, and hazard mitigation.

Student-Centered Evaluation of a GIS Laboratory in Transportation Engineering

Abstract

This paper focuses on the implementation of a Geographic Information System (GIS) based transportation module part of a web-based learning system for civil engineering students. This project introduces a series of GIS laboratories customized for specific courses throughout the civil engineering curriculum. This exploratory research presents the results of a student-centered evaluation of the laboratory introduced in a required introductory transportation course. Results showed that students exposed to a 20-minute lecture on traffic safety before starting the laboratory scored significantly higher than the control group on assessment items. The student-centered reflective questions indicated also some weaknesses and associated potential actions to improve the GIS based module. Based on these findings a series of changes to the current tasks in the GIS laboratory were planned.

KEYWORDS

Transportation Education and Training, Traffic Safety, Crash Data, Geographic Information Systems

Introduction

The education and practice of transportation engineering has evolved over the past several decades. The task of transportation education, as stated by an Institute of Transportation Engineers (ITE) Committee[1], is not only "*to train students in how to do various activities associated with current practice*", but also "*to provide students with the tools necessary to solve new problems that arise*". Previous studies, on the other hand, reveal the hourly requirement of transportation-related courses in the civil engineering curriculum offered for undergraduate students as decreasing[2,3] and entry-level engineers lack significant exposure to transportation engineering methodologies[2]. In terms of practice, young graduates face a wide range of increasingly complicated problems from growing congestion, *heightened awareness of traffic safety* and worsening air quality to environmental preservation and social equity concerns[4].

In a survey[4] of 360 participants of transportation engineering and planning courses offered at US universities, while assessing the match between the knowledge (topics) and the skills needed for current transportation planning jobs and those covered by their formal degree programs, respondents indicated that their degree programs did not provide enough exposure to any of the 20 skill areas surveyed in the study. In the skills category, GIS received the lowest average rating for coverage. When the topic and skills most in need of additional attention were assessed for transportation planning education, again GIS was identified as one of the top priority skills. The study also showed a greater deficiency in the development of skills than in the coverage of topics in academic programs. This clearly showed the need for inclusion of GIS in civil engineering curriculum especially for transportation planners.

To resolve some of the above issues, the transportation engineering curriculum (including both topics and teaching methods) needs to be more rigorous and technically focused to meet market needs[5]. In recent years, web-based education has become a popular and effective way of complementing classroom instruction. Online learning tools bring a classroom laboratory right in front of a student on the computer. Web-based learning tools also offer the benefit of platform, independence of location, and flexibility of usage. The learning tools can be accessed anytime and from anywhere around the world from computers with Internet access[5].

Smith and Cunningham[6] describe the ideal learner as one who is active and is involved in the learning process by asking questions, teaching others, or participating in hands-on activities. They showed that these learners more often develop a comprehension of the ideas and concepts of the material being presented and do not just memorize the facts being presented. Their conclusion was that active learners are more often able to apply the learned skills to new situations. In this context, a study that included a survey of more than 4000 adult learners from a variety of backgrounds who participated in a training project at the University of Tennessee Transportation Center[7], identified hands-on exercises as very useful and often described how much fun they had learning the material in this format.

To address the above needs and following the formats and active learning environments, a National Science Foundation (NSF) sponsored research project focused on developing and implementing a web-based learning system for civil engineering students[8]. This NSF project introduced a series of GIS laboratories customized for specific areas in the civil engineering curriculum such as Environmental, Geotechnical, Surveying, Transportation and Water Resources engineering. A web-based learning system was developed to scaffold learning across various area-specific modules to introduce GIS to civil engineers. Figure 1 shows two examples of the level of detail and richness of content available to students, such as built-in videos that can be played in parallel as they are conducting the learning exercises. The embedded video depicts a query builder session of the laboratory as the student is exploring and interpreting the crash data.

The learning model proposed by this NSF sponsored research is a distributed learning model using individual, one-time laboratories across several civil engineering complementary courses. This distributed learning model is intended to build GIS-related skills by contextualizing the software application mentioned in various topics across the civil engineering curricula. Under this learning model, students will move from mere learning of the mechanics of use of GIS to a broader understanding of the capabilities and importance of this tool for various civil engineering applications. The mechanics of programming will then become a cumulative result of this string of individual implementations of the GIS software.

To address the goal of the above mentioned distributed learning model this paper focused on the impact of such a contextual implementation of the GIS software in Transportation Engineering, a mandatory first course in transportation for civil engineers. Therefore, the focus of this research will be a one-time laboratory introduced in this course with the emphasis on students' results and perceptions related to this laboratory activity.

Instructional Context

The main goal of the GIS laboratory presented in this paper was to introduce traffic safety using the ArcGIS® software. During the laboratory, students completed three major instructional tasks: 1) a self-paced multimedia tutorial that introduced the steps associated with the use of ArcGIS® for each stage of the task at hand using a simplified crash dataset; 2) a transfer task that required students to use the steps described in the tutorial for a given field-based dataset; and 3) a synthesis task that required students to write a short report on their findings, in this case the safety issues found with the provided dataset.

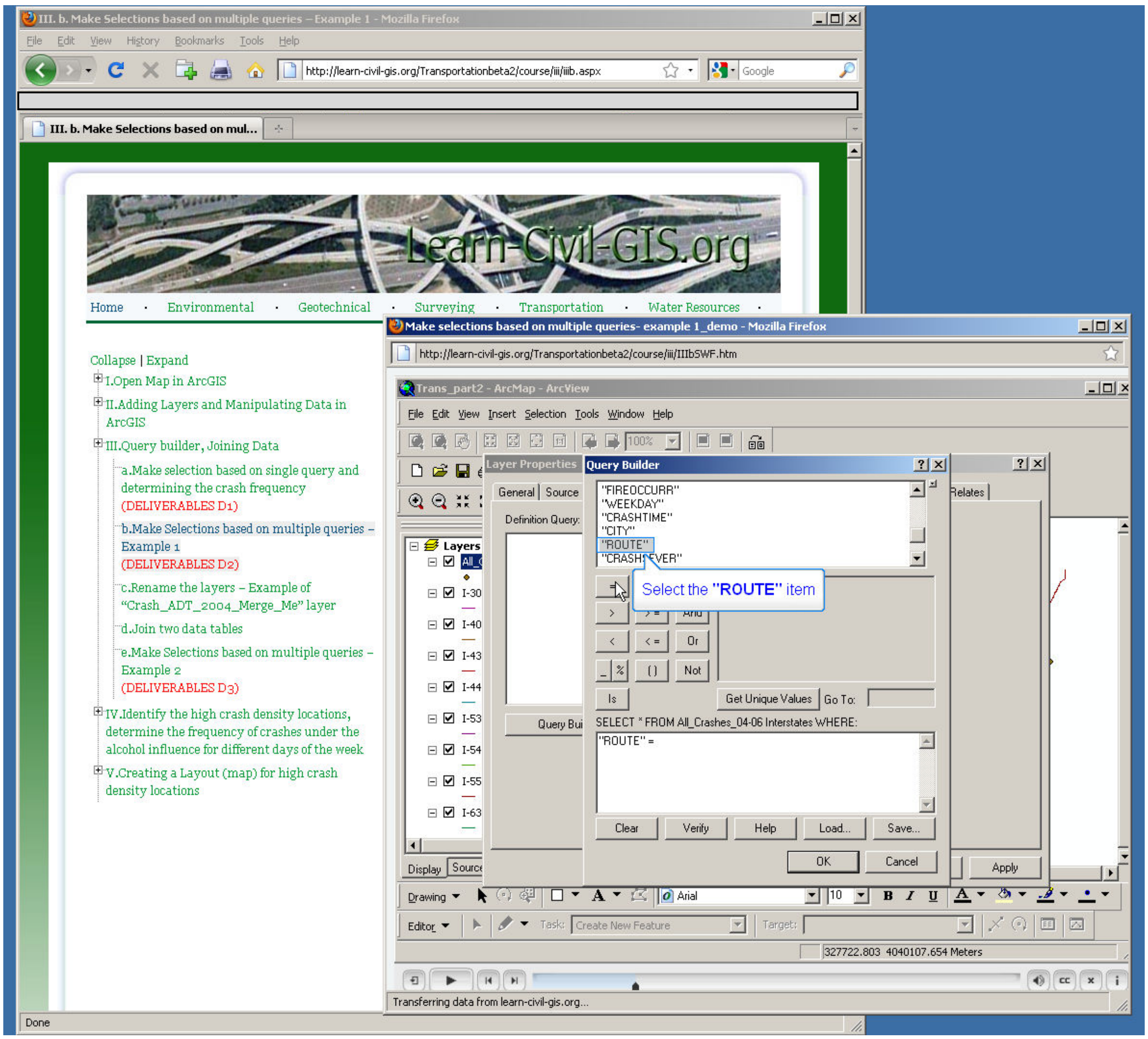

Figure 1 – Example web-based screen showing the embedded video for query building.

In Spring 2009, the GIS laboratory was first tested on a small scale with six students as part of one of the final transportation laboratories. The trends identified from the exit survey administered showed that overall students engaged in this implementation found it to be interesting and motivating.

Their positive feedback was also backed by the fact that even if the time required by this first version of the GIS laboratory was more than the three laboratory hours allocated for this activity, all students were able to complete it. The online learning environment was then tested by an instructional designer with an engineering background but not familiar with any GIS software. Using both the students and instructional designer's feedback, minor modification in the sequence and structure of existing tasks were implemented in a new version of the online environment. In addition, several conceptual and procedural changes were made of the online environment for implementation during the Fall 2009 semester.

First, the focus changed from the procedural aspects of operating the GIS software toward the use and importance of GIS data analysis on traffic safety. This change was grounded in the basic assumptions of situated learning models[9,10] which state that learning is mainly a function of an activity, context or culture in which it occurs. In this case, learning of GIS software will be stimulated in the context of the course where it is introduced, in this case traffic safety associated with transportation engineering issues. To test the potential impact of switching the emphasis of the laboratory activity from the GIS software toward highway safety issues, students were divided into two groups: 1) the control group that started directly in the computer laboratory with a graduate teaching assistant helping them as needed; and 2) for the treatment group, before going to the same laboratory activity as the control group, students were exposed to a short lecture that created awareness on traffic safety issues and their consequences for traffic analysis and design. Due to the short duration of this intervention the expectation was that the treatment will increase students' awareness on the importance of the laboratory activity and traffic safety issues which will be reflected in better learning performance but will not significantly impact treatment students' overall perception of the laboratory activity.

In the following semester, a second change, the GIS laboratory was administered earlier to improve the overall management of the course. It was offered during the first week of class when commonly the content-related laboratory time is not used effectively as the lectures have not yet progressed significantly. This change was considered effective because at the conceptual level it focused on common-knowledge traffic safety issues to be analyzed using field-based datasets.

Finally, a more structured, student-centered feedback and assessment program that started with an entry survey and ended up with a reflective assessment of the GIS laboratory activity and an exit survey was designed and implemented.

Research Questions

The overall objective of this evaluation was to assess to what degree the GIS laboratory was a useful tool for a civil engineer undergraduate engaged in a transportation engineering course. The main exploratory research questions were:

- (R1) Is the GIS laboratory an effective tool for learning traffic safety?
- (R2) Does the grounding of GIS activity in a traffic safety context produce better learning?
- (R3) Do the students find the laboratory useful from a professional growth perspective?

Research Methods

Participants

Twenty seven students mostly juniors and some seniors all enrolled in an mandatory introductory Transportation Engineering course participated in the study. The average self-reported GPA of the class was 3.0, ranging from a minimum of 1.9 to a maximum of 3.8.

Procedures

During the first class lecture, students completed an entry survey that measured their motivation, self-reported level of skills, and assessed their prior knowledge on basic topics associated with the contents of the course, Transportation Engineering. A set of eleven nine-point differential-scale items were developed for this study and used to measure students' motivation, perceived difficulty and perceived usefulness of this course (see Appendix 1). Students were also asked to self evaluate on a five-point, novice to expert scale, their skills associated with critical computer applications (e.g. AutoCAD, Excel, PowerPoint) and tasks (e.g. presentations, report writing) and to answer a set of assessment questions on basic math, physics and surveying, all considered important for students' success in the course as a whole. Of the 27 students enrolled in the course 24 completed the entry survey. In addition, the GPAs at the beginning of the semester were collected for 26 of the students enrolled in this course (one international transfer student enrolled in this course did not have a GPA-equivalent score).

Then, the GIS laboratory was set as a first week's laboratory activity for the course, following the first class lecture. The GIS laboratory was set up as a self-guided experience with high demand on students which potentially create challenges for students engaged in introductory courses. To address this potential challenge, a quasi-experiment was run to test if an additional introductory activity will enhance the learning experience for this laboratory. That is, before engaging in this first laboratory, students were split in two groups. They were asked to choose between going directly to the laboratory (control group) and going to a 20-minute lecture with the instructor before starting the laboratory (treatment group).

Of the 27 students participating in this study, 11 went directly to the laboratory (control group) while 16 went to the 20-minute lecture before starting the laboratory (treatment group). The meeting for the treatment group served as awareness builder on traffic safety issues and the potential benefit of GIS software in addressing them. The actual laboratory activity was scheduled for three hours with an extension of about half hour offered for the students in the treatment group. Two graduate teaching assistants supervised this activity and helped students overcome various technical and conceptual challenges posed by various tasks of this activity.

Even if most of the tasks were covered during the laboratory time, students were given one week to finalize and review the data and then summarize their findings in a short report. At the beginning of the next laboratory, after submitting their report for the GIS laboratory, students participated in an unannounced exit survey. This exit survey was administered online in the laboratory and contained the same set of motivation and usefulness items used in the entry survey along with a set of academic self-efficacy scale[11,12] .

In addition, the exit survey contained seven multiple-choice assessment items focusing on traffic safety data that resulted from their data analysis. These assessment questions ranged from simple recall questions related to the ArcGIS software (e.g. *Using "Query Builder" in ArcGIS® we can locate specific types of crashes*, True/False/I don't know) to more specific fill-in-the blanks multiple-choice questions based on the results of the laboratory activities (e.g. *Based on the data analyzed in the GIS lab, I found _________ to have the highest frequency of crashes involving alcohol*, Monday/Sunday/ Saturday/I don't know).

Finally, the exit survey also contained several open-ended reflective questions regarding students' experience with the GIS laboratory and their perception of its professional usefulness.

Research Design, Results and Interpretation

A quasi-experimental design was used for this study. Students could choose between going directly to the laboratory (control), and going to a 20 minute lecture with the instructor before starting the laboratory (treatment).

<u>Quantitative Analysis</u>

Measures

For the quantitative analysis, the three categories of variables used were:

a) *control variables* used to test the homogeneity of the two experimental groups
    - Aggregate prior knowledge score, resulted as a percentage of total score for the prior knowledge questions on basic math, physics, and surveying administered with the entry survey;
    - Entry GPA score, self-reported by students and validated using the internal reporting resources available;

b) *dependent variables* used to assess students' performance on seven traffic safety questions administered with the exit survey:
    - Raw assessment score resulted from students' answers to the seven multiple-choice and fill-in-the-blank assessment items focusing on traffic safety data administered in the exit survey. For each of the seven assessment questions, a value of "1" was allocated for a correct answer and a value of "0" for a wrong answer. The raw assessment score resulted as a percentage of the sum of answers to the seven assessment questions to maximum possible score (7 in this case).
    - Adjusted assessment score considered the fact that students had "I don't know" as one of the options for each of the seven multiple-choice assessment questions above mentioned. Therefore, the adjusted assessment scores included a penalty for students that answered wrong even if they could choose "I don't know" option. That is, a "0" was given for a wrong answer, a "1" was given for selecting "I don't know" and finally a "2" was given for a correct answer. The adjusted assessment score was computed as the percentage of the sum of answers to seven assessment questions to maximum possible score (14 in this case).

- Exit self-efficacy, self-reported motivation, perceived usefulness, and perceived difficulty of laboratory activity measured with the previously mentioned tool and ranged from 1 to 5 for self-efficacy and from 1 to 9 for motivation, usefulness and difficulty.

c) *independent variables*
- Experimental groups (11 students for the control group and 16 students for the treatment group) and,
- Self reported time-to-finish on task collected on the following scale 1–by the end of regular laboratory time; 2–by the end of extended laboratory time (to compensate the lecture time for treatment group); 3-later in the day of the laboratory; 4-the week of the laboratory; and 5-the week following the laboratory before the report deadline.

Analysis of Basic Statistical Data

Table 1 presents the basic statistics for continuous measures used in this study. The raw assessment percentages ranged from a minimum of 28.6 to a maximum of 100 with a mean of 70.4, while adjusted assessment percentages ranged from a minimum of 57.1 to a maximum of 100 with a mean of 76.4. Considering the relatively short duration of the learning activity and the unannounced follow-up testing, these results show an overall good performance outcome for the traffic safety issues when the GIS laboratory activity served as learning scaffold (R1). These findings suggest a first positive trend in answering the exploratory research question (R1) associated with the potential impact of this laboratory to scaffold learning traffic safety.

The bivariate correlations (see Table 1) also revealed that students' entry GPA showed a statistically significant, moderate-to-high positive correlation with the perceived motivation ($r = .67$, $p < .01$) and usefulness ($r = .53$, $p < .01$) of the GIS laboratory activity. However, no strong insight can be formulated for the difficulty of this activity as on one hand, no significant correlation of GPA with the perceived difficulty of the task was found but a moderate statistically significant negative correlation ($r = -.45$, $p < .05$) between perceived difficulty and academic self-efficacy (a measure of trust in own ability to perform well in this laboratory) was found. The lack of statistical significance for the negative correlation between students' GPA and perceived difficulty suggests that a large number of students with high GPA found the laboratory more difficult than typical similar laboratory activities, suggestion that supports the need for an analysis of the level of difficulty of laboratory activity.

Table 1: *Means, Standard Deviations, and Pearson Correlations for continuous variables*

	M	SD	2	3	4	5	6	7
1. Raw Assessment [a]	70.4	17.2	$.83^{**}$	.04	.11	-.29	-.00	.05
2. Adjusted Assessment [a]	76.4	11.6	-	.12	.25	-.18	.09	.06
3. Entry GPA [b]	3.0	.5		-	$.67^{**}$	-.17	$.53^{**}$	.12
4. Perceived Motivation [c]	5.4	1.0			-	-.10	$.52^{**}$	.23
5. Perceived Difficulty [c]	6.4	1.6				-	-.15	$-.45^{*}$
6. Perceived Usefulness [c]	6.3	1.0					-	.19
7. Academic Self-Efficacy [d]	3.4	.6						-

Notes: $^*p < .05$; $^{**}p < .01$;
[a] Percentages; [b] 0 to 4 scale; [c] 0 to 9 scale; [d] 0 to 5 scale

Analysis of Experimental Data

An independent-sample t-test indicated no statistically significant differences at entry for:

a) the aggregate prior knowledge scores of the two experimental groups (N=24), $t(22) = -.168$, $p = .87$
b) GPAs of the two experimental groups (N=26), $t(24) = -.79$, $p = .44$.

Based on these results it can be concluded that the two experimental groups were homogeneous from a learner characteristics perspective.

To test the second research question (R2), results were also analyzed using an independent-samples t-test (N=27). The analysis revealed a significant difference between mean levels of performance for both raw assessment scores, $t\ (25) = -2.142$, $p < .05$, and adjusted assessment score, $t\ (25) = -2.155$, $p < .05$.

For both the raw and adjusted assessment scores, the treatment group having 16 participant scored significantly higher ($M_{t\text{-raw}} = 75.9$, $SD = 16.3$; $M_{t\text{-adjusted}} = 79.9$, $SD = 11.7$) than the control group having 11 participants ($M_{c\text{-raw}} = 62.3$, $SD = 16.0$; $M_{c\text{-adjusted}} = 70.8$, $SD = 9.3$).

These results support the positive impact of explicitly (instructor-stimulated awareness) grounding the laboratory activity on students' performance on traffic safety questions. However, no significant differences between the two experimental groups were found for the exit perception and attitude variables: a) perceived motivation, $t\ (25) = -1.07$, $p = .30$; b) perceived usefulness, $t\ (25) = 1.19$, $p = .25$; c) perceived difficulty, $t\ (25) = -.43$, $p = .67$; and d) academic self-efficacy, $t\ (25) = 1.34$, $p = .19$. These findings support the initial expectation that the treatment was too short (20 minutes introductory lecture) to produce a significant difference on students' perceptions of and attitude toward the laboratory activity.

As students reported different time-to-finish, further tests were carried out to find if this time on task had an impact on their performance on the traffic safety assessment items. Due to the relatively small number of students, time-to-finish was re-coded using a median split that resulted in two values: 1-finished same day and 2-finished later in the week or week of the deadline.

An independent-sample t-test indicated no statistically significant difference between the treatment and control group for both raw assessment scores, $t(25) =.33$, $p = .75$, and adjusted assessment scores, $t(25) = -.31$, $p = .76$. This finding strengthens the previous finding that the increased time on task allowed to compensate for the lecture time did not significantly impact the performance outputs as it did the exposure to the short context-awareness lecture.

Qualitative Analysis

The main goal of this analysis was to identify themes associated with the exploratory research questions that reflect students' perception of this laboratory (R1 and R3). The qualitative analysis used an in-vivo coding of students' answers to four open-ended questions[13]. A first question (question 1), overall opinion about the laboratory experiences, targeted the factors that made the highest impact on students' perception of this laboratory.

Next two questions (question 2 and question 3) targeted more specific factors such as the perceived strengths and weaknesses of the laboratory experience on: a) motivation to learn about traffic safety (question 2), and b) applicability of GIS laboratory to real world activities (question 3). The final question asked for suggestions to improve the current laboratory experience (question 4).

On the positive and strengths side, several encouraging themes were found in students' inputs to these open-ended questions as follows. Overall, 16 students (59.25%) out of 27 found this laboratory activity interesting, useful, real-life like or well supported by the online tutorial. The following selected answers provide a summary of these perspectives. The italicized comments indicate the highlights of the student's comment and for the interested reader the detailed comment is also presented:

> Student 5
> R[espondent]: I found the lab to be *very useful and I was glad to have the opportunity to use programs that would possibly be useful after I graduate*. It was extremely helpful having the GTAs to answer questions, especially when I was learning to use the query builder. I would enjoy the opportunity to use other programs that are actually used in the field of transportation engineering. (309 characters, question 1)
>
> Student 7
> R: I believe that the *GIS lab was very interesting*. Using the data provided I could develop *maps and graphs that helped me understand the crash sites*. The map was very helpful to me because I could see where all of the crash sites were located. This lab was well done. (216 characters, question 1)
>
> Student 9
> R: *The tutorial was very helpful and detailed* so there was minimal effort in following the steps. Overall, the lab was not easy nor overly hard. (117 characters, question 1)
>
> Student 14
> R: I thought that the lab was *overall a good way to introduce the GIS system to us*. The lab could have had a few less steps, but all in all it was a well put together. (216 characters, question 1)
>
> Student 22
> R: The GIS lab was *a very good way for first time users to become familiar with GIS*. I have never used this application before; therefore, it was very good for me to have a walk through with help before having to do an assignment. *I believe it can be very beneficial to a transportation engineer,* but someone focused on buildings would not need to learn this system; however, I believe it is important for everyone to have a little knowledge of the system. *The lab had very clear instructions and guided me through the entire process.* (436 characters, question 1)

Out of the 16 students that had an overall good perception of the GIS laboratory, 10 were part of the treatment group (attending the initial short lecture on traffic safety), a finding that strengthen the results from the quantitative analysis regarding the positive impact of the treatment on students engaged in this activity.

When answering specific questions on the strengths of this laboratory, students focused on several themes as follows.

It was a motivational activity

Student 7

R: *The GIS lab was very motivational to me*. It made me wonder what a transportation engineer could do to decrease the amount of crashes on interstate highways and to make them safer. *I am very interested in seeing what else it can do*. (189 characters, question 2)

Student 16

R: I think using the query to sort through the information was very interesting and very useful in analyzing traffic safety. *Using this program, once you know how to use it, I think would be a great motivator for students.* (181 characters, question 2)

It provided helpful visual representations

Student 1

R: I am interested in learning about traffic safety. GIS just helps me better understand problems on the road. *It visually presents traffic safety issues*. (128 characters, question 2)

Student 8

R: Strengths: all the statistics were very interesting, *making graphs helped me understand everything better.* (93 characters, question 2)

Figure 2 exemplifies the activity when the student is preparing a map as a final deliverable of the spatial and visual representation of their work. The main figure shows the five major steps involved in the learning activity. The figure on the lower right hand side, shows' results of the activity: high-density crash locations around Little Rock, Arkansas.

It is a real-world/hands-on activity

Student 14

R: *This was very much a "real world" application*. The strengths of this are that these skills *can be used outside of this class at an actual job* and overall this helps prepare for the types of things that would happen in a "real life" type of scenario. (203 characters, question 3)

Student 17

R: Strengths of the lab in terms of *my educational value would be basically getting a more hands-on learning experience*. Doing labs such as the GIS lab *seem to be representative in what I will see in a real career as a civil engineer.* This lab allowed me to see where most accidents occur and what factors may have played a role. (266 characters, question 2)

It is helpful for highway design, monitoring and decision-making on traffic safety issues

Student 22

R: Strengths: showed the *details that must be looked at while designing highways*, allowed me to see how certain conditions play a role in accidents, want to know how to use it in more detail and what engineers do to fix some of the problems identified*, how the latest technology can be used to design.* (245 characters, question 2)

Student 17
R: Strengths in real world applications of this lab would mainly be getting the hands on view at traffic safety. It seems to be a tool that *could be used in the real world to monitor traffic* and give factors that could have contributed to accidents. (202 characters, question 3)

Student 24
R: This program has *a lot of potential in real world activities* both in the decision making process for highway safety and verification of highway safety improvements. (139 characters, question 3)

Student 11
R: The software seemed to be easily brought into a real world situation to *discuss high crash data and work with engineers and the community to provide safer highway systems*. (143 characters, question 3)

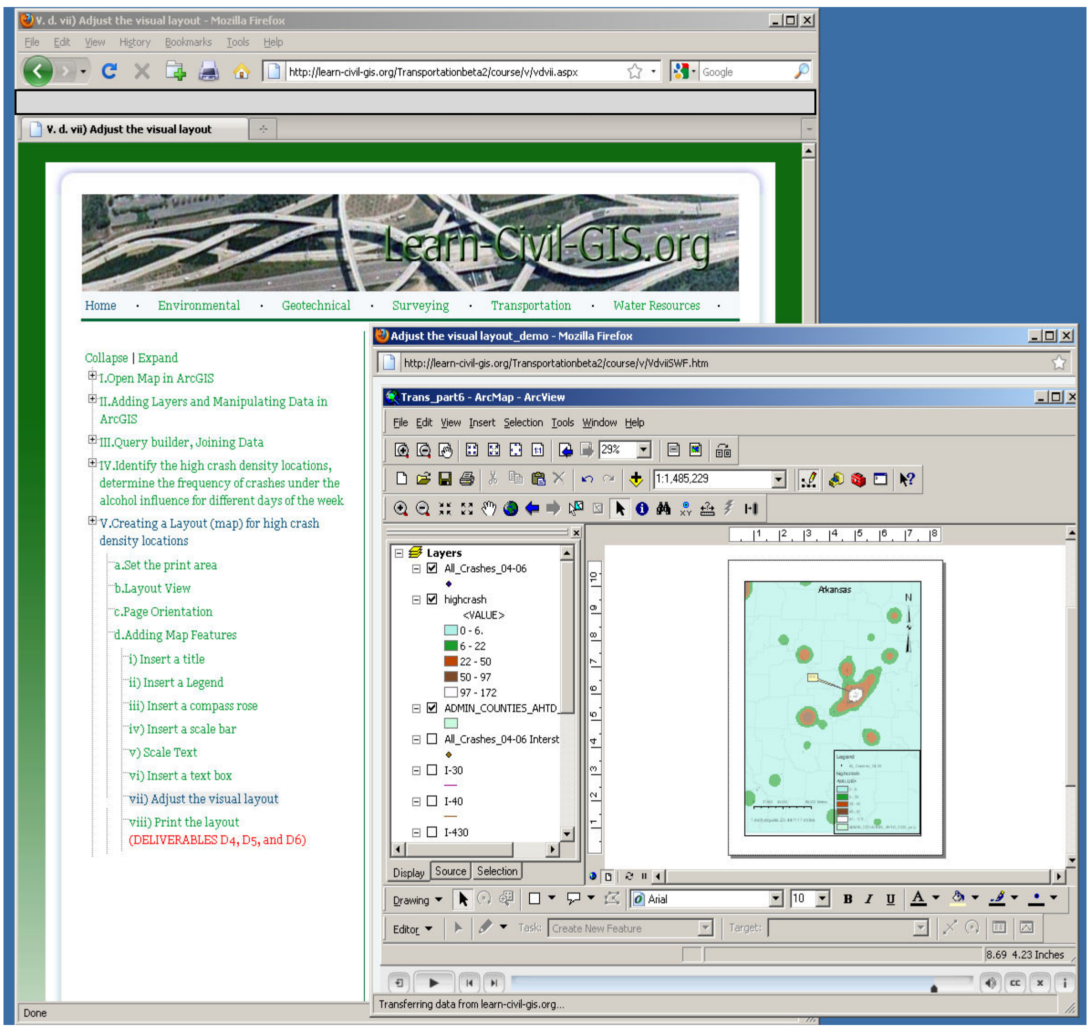

Figure 2 – Example of student's final deliverable: visual representation of data.

The above themes identified in students' perceptions of the strengths of the GIS laboratory offer a strong support for two of the three exploratory research questions. That is, students see this laboratory as both an effective scaffold for learning traffic safety issues (R1) and a useful tool for professional growth as civil engineers (R3).

On the weaknesses part, most of the comments focused on the activity being too long and frustrating.

> Student 4
> R: *This lab would have been beneficial if it wasn't so long*. It needed to be broken up in to more than one lab time. When I got to about the halfway point I was very tired and frustrated. It was hard for me to do even with the step by step instructions… (198 characters, question 1).

> Student 10
> R: I feel like the GIS lab was beneficial and informative but *the excessive time to complete this assignment took away from the overall effectiveness.* (123 characters, question 1)

> Student 14
> R: As for weaknesses, I think *the lab could have been a little bit more condensed* to keep us interested for the entire period. (101 characters, question 2)

> Student 20
> R: Weaknesses: *it was very long and tedious which caused me to lose interest in actually learning the lab materia*l, and caused me to just want to be done with it. (130 characters, question 2)

Other weaknesses covered technical and implementation-related issues that deterred students' engagement and motivation such as lack of clarity for some steps (especially the query building ones), lack of explanations on the role of various steps in the activity, or lack of a strong real-world scenario to ground the required laboratory tasks.

> Student 18
> R: … Our particular lab seemed to be very long and *at times confusing. There are many things that could go wrong with the query builder and that is [the task] where I had my trouble*. Overall, I understood what was wanted but just could not convey my thoughts through the program. (225 characters, question 1)

> Student 9
> R: Weaknesses: *Steps did not tell the reason for doing them while it was being done*, which made the lab more like just following the steps. (112 characters, question 2)

> Student 6
> R: The lab is useful however it needs to be explained why it's useful before attempting to do the lab. The steps from the website were not self-explanatory so the need of the GA was very critical. (158 characters, question 1)

> Student 23
> *R:* *I would have liked the lab better if it had a real world scenario in it*. The lab I did was more of a introduction. If I needed to use the GIS for real world activities based on what I learned in this lab I would not be able to accomplish it without an external source for help. (219 characters, question 3)

These weaknesses reinforce the findings from the quantitative analysis that showed a non-significant negative correlation between students' GPAs and perceived difficulty of laboratory activity. That is, even students with overall good academic performance found various aspects of this laboratory more challenging than expected.

Finally, students' suggestions for improvement addressed all major weaknesses and focused on *the need for*:

- *a more detailed instructor-lead overview of the laboratory activity*;

> Student 1
> R: I think *at the start of the lab, there should be an introduction to ArcGIS section*. Here students should be given a brief overview of what it does, what it contains and how to use basic functions. (160 characters, question 4)
>
> Student 14
> R: The only improvement suggestion that I have would be to *do a little more instruction using the software in front of the class, maybe even with some explanation as to what we are actually doing when using certain commands.* This may keep people more interested in the lab and also could help people who had questions on how to do certain things that were in the lab. (298 characters, question 4)

- *the balancing of the volume and length of the activity*;

> Student 4
> R: *It could be broken up into more than one lab*. Maybe even let us do some simpler labs on it first before you have us do something more complicated. (118 characters, question 4)
>
> Student 20
> R: *The lab should be separated and spread out into 2 or 3 different labs.* It took too long to complete this one lab assignment. Someone such as the teacher should go over how to do the lab parts before the students actually try their hand at it, rather than just having a tutorial teach us everything. (241 characters, question 4)

- *more specific information and better technical features for some problematic tasks*.

> Student 18
> R: *The activity could be improved may be a better understanding of the query builder*, it is where I had my most trouble. This made the lab time consuming and hard to stay motivated to complete. Overall it was very useful but only had a few minor flaws. (204 characters, question 4)
>
> Student 26
> R: There were parts of the instructions which were unclear, and *it would be an improvement to have little graphics of the buttons in the text format of the instructions so that the buttons on the toolbars can be identified easier.* (188 characters, question 4)

Conclusions and Further Research

Overall, both the quantitative and qualitative data collected indicated support for the exploratory research questions that motivated this study suggesting that:

a) Overall, the GIS laboratory supports learning of traffic safety issues associated with civil engineering,

b) Grounding the learning activity in a traffic safety context produces both better learning outcomes and more positive student perception of this laboratory as a whole, and

c) Students engaged in this laboratory perceived it as hands-on activity with strong links to real-world activities of a civil engineer.

In addition, the student-centered reflective questions developed and administered in this study helped to identify existing weaknesses in the GIS laboratory and associated potential measures to address them. Based on these findings a series of changes to the current tasks in the GIS laboratory have been performed. First, the whole task will be anchored[10,14] in a scenario that resembles the introduction to traffic safety offered to the treatment group.

Next, the steps in the online tutorial will better follow the steps associated with traffic safety and the explanations associated with these steps adjusted accordingly. Finally, the reviewed laboratory structure will eliminate the transfer task in favor of a detailed one-step data analysis followed by a more consistent final report focusing on traffic safety. This is being implemented and the impact of this new structure of the tasks will be studied in the coming semesters.

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Appendix 1: Motivation, Usefulness and Difficulty Scales

dif1 – M1	**Boring (low)**	1	2	3	4	5	6	7	8	9	**Interesting (high)**
dif2 – D1	**Easy (low)**	1	2	3	4	5	6	7	8	9	**Hard (high)**
dif3 – U1	**Useless (low)**	1	2	3	4	5	6	7	8	9	**Useful (high)**
dif4 – M2	**Dull (low)**	1	2	3	4	5	6	7	8	9	**Lively (high)**
dif5 – D2	**Painless (low)**	1	2	3	4	5	6	7	8	9	**Painful (high)**
dif6 (r) – U2	***Valuable(high)***	1	2	3	4	5	6	7	8	9	***Worthless (low)***
dif7 (r) – D3	***Complicated (high)***	1	2	3	4	5	6	7	8	9	***Simple (low)***
dif8 – U3	**Textbook like (low)**	1	2	3	4	5	6	7	8	9	**Real World like (high)**
dif9 – M3	**Dry (low)**	1	2	3	4	5	6	7	8	9	**Motivational (high)**
dif10 (r) – U4	***Practical (high)***	1	2	3	4	5	6	7	8	9	***Theoretical (low)***
dif11 (r) – D4	***Labor-intensive (high)***	1	2	3	4	5	6	7	8	9	***Effortless (low)***

Notes: (r) *reversed-scale questions*;
M – Motivation: [dif1+dif4+dif9]/3
D – Difficulty: [dif2+dif5+dif7(r)+dif11(r)]/4
U – Usefulness: [dif3+dif6(r)+dif8+dif10(r)]/4