



Integration of Information Technology Software in a

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Integration of Information Technology Software in a Civil Engineering Program – Learning Styles Considered

Abstract

Expectations of information technology skills continue to grow in the Civil Engineering profession, demanding that universities include the development of information technology knowledge in their vision and goals, and ABET outcomes and objectives. Since 2007, the Civil Engineering Program at the United States Military Academy has evolved their approach to integrating information technology into multiple courses across the program. In 2009, a comprehensive study was conducted to assess the effectiveness of this approach and three specific challenges were identified: limited faculty capacity to maintain pace with the information technologies, complexities and costs of the technologies, and difficulty of integrating the technologies across a program rather than a one-course exposure. In the following years, these challenges were addressed and teaching approach to information technology evolved to address these challenges. In 2011, a follow-up study was completed to assess the evolution and identify future work to continue to evolve the approach. Specifically, it was reported that through the evolution and assessment it became readily apparent that there was a unique and strong relationship between learning styles and teaching/tutoring approaches. Although this is an obvious statement relative to all learning and teaching environments, the demands of teaching information technology across multiple domains of development (cognitive, affective, and psychomotor) made this connection even more critical. This paper will discuss the study of the learning styles considerations in teaching information technology and how teaching/tutoring approaches can best be developed to address student learning styles across multiple domains of development. Longitudinal assessment results will be compared to the 2009 and 2011 studies, along with other assessments. It is believed that these results, and the continued assessment of the teaching approach at this institution, will provide valuable insight to other programs to help them overcome the challenges of teaching information technologies.

Introduction

The purpose of this paper is to present the results of the assessment of the continued efforts to improve the learning and teaching of a site design software package in the Civil Engineer program at the United States Military Academy. The results are an extension of two previously published papers: *Integration of Information Technology Software in a Civil Engineering Program* (2009, Caldwell et. al.)¹ and *Integration of Information Technology Software in a Civil Engineering Program – A Follow-Up* (2011, Toth et. al.)². In particular, the recommendation by Toth in 2011 to consider learning styles in the development of the learning path for the software will be discussed. The paper includes background information on the Civil Engineering program at the United States Military Academy and information technology software used in the same program, an outline of the course which uses the site design software and the challenges associated with integrating the software into the course. Finally, the most recent changes undertaken to address the challenges and an assessment of the changes will be presented.

Motivation and Challenges of Information Technology in Civil Engineering

The modern civil engineer is expected to apply information technology skills to model and design projects. These expectations are articulated in Outcome 10 of the American Society of Civil Engineers (ASCE) *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future (BOK2)*³, which references Outcome 3k of ABET Inc. *Proposed Criteria for Accrediting Engineering Program*⁴. The *BOK2 Levels of Achievement Subcommittee* recommends that civil engineers who have earned a baccalaureate degree should be able to achieve the third level (application) of the six-level cognitive domain in this outcome. At that level, graduates should be able to³:

- **List** the techniques, skills, and modern engineering tools that are necessary for engineering practice.
- **Explain** how these techniques, skills, and modern engineering tools are used in engineering practice.
- **Apply** relevant techniques, skills, and modern engineering tools to solve problems.

These needs were recognized by Grigg et. al. (2005)⁵, Clough (2000)⁶, and Bordogna (1998)⁷. The specific obstacles to meeting these needs were identified by Grigg et. al. (2005)⁵ and confirmed by Caldwell et. al.¹ (2009) and Toth et. al. (2011)²:

- 1) Limited faculty capacity to maintain pace with the technologies,
- 2) Complexities and cost of the technologies,
- 3) Difficulty of integrating the technologies across a program rather than a one-class exposure.

Civil Engineering Program at the United States Military Academy

The mission of the United States Military Academy has evolved since the institution's inception in 1802⁸:

To educate, train, and inspire XXXXXXXX so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country, and prepared for a career of professional excellence and service to the Nation as an XXXXXXXXXXXXXXXX.

The Department of Civil and Mechanical Engineering is one of thirteen academic departments at the United States Military Academy and is ABET accredited. The Department's mission supports the Academy's with focus on educating and inspiring students in the fields of civil and mechanical engineering⁹:

To educate students in civil and mechanical engineering, such that each graduate is a commissioned leader of character who can understand, implement, and manage technology; and to inspire students to a career in the XXXXX and a lifetime of personal growth and service.

The Civil Engineer program recognizes the technology element of the Department's mission statement and established a specific ABET program outcome, "Use modern engineering tools to solve problems." The program assesses the outcome through a variety of sources, to include embedded indicators, which are preselected requirements in courses across the program^{10, 11}.

There are a wide variety of information technology software packages used as the modern engineering tools in the Civil Engineering program. Spreadsheets (*Excel*) and mathematical programs (*MathCAD*) are used in many courses and several courses use specific programs:

- Site Civil Engineering Design: *ArcGIS* and *Civil3D*
- Geotechnical Engineering: *Slope/w*
- Hydrology/Hydraulics Engineering: *HEC-RAS* and *HEC-HMS*.
- Advanced Mechanics of Materials: *SolidWorks* and *Autodyn*
- Structural Analysis: *ROBOT* and *REVIT*
- Advanced Structural Analysis: *ROBOT*, *MASTAN*, and *CONWEP*
- Construction Management: *MS Project*, *Google Earth*, and *Google SketchUp*
- Transportation Engineering: *STREET*

The intent of the Civil Engineering Program's capstone course is to then integrate all the individual course's information technology in a comprehensive project. Additional discussion and information about the capstone integration can be found at Caldwell et. al.¹ (2009) and Hart et. al. (2009)¹². This paper will focus on the *Civil3D* software in the Site Civil Engineering Design Course because this is essentially the first course where information technology is introduced in the Program.

Site Civil Engineering Design Course

The Site Civil Engineering Design Course (CE390) is a site design and land development course required by all civil engineering majors in the first semester of their junior year. This course provides students with the necessary background to select and develop sites for civil engineering infrastructure. Specifically the course covers the skills of determining site layout and access, establishing site contours and drainage, installation of utilities, elementary surveying, creation of site models using advanced civil engineering software, and the development of environmental impact statements¹³. The course textbook is the Dewberry Company's *Land Development Handbook, Third edition*. The course is structured around the seven steps of land development outlined by Dewberry: 1) feasibility and site analysis, 2) programming, 3) conceptual design, 4) schematic design, 5) final design, 6) plans submission and permitting, and 7) construction¹⁴. Course content is taught using traditional classroom instruction, homework problems, exams, and a major engineering design project (EDP) in groups. The EDP is a real-world scenario based on an ongoing or potential land development projects at the United States Military Academy. The students receive a project proposal and then work through the schematic design phase of land development. The most recent EDP (fall 2012) was the development of a residential community. The problem statement included the option to keep/remove existing structures and then redesign the 70 acre site to include ten residences, ten vacation cabins, a recreational lodge, a natural swimming pool, outdoor athletic courts, a playground, a neighborhood garden and supporting parking and traffic network necessary to facilitate access to the new community. A civil engineering modeling software package (*Civil3D*) is the primary tool used by the students for completion of their final schematic design products: final site layout, design for earthwork grading, storm water management design, and transportation system. CE390 serves as student's first exposure to this software tool.

Civil 3D is a comprehensive design solution from *AutoDesk* for site modeling, land development, and planning for projects ranging from residential to civil infrastructure. It is a multidisciplinary tool that supports Building Information Modeling Processes and integrates capabilities for survey, digital terrain modeling, site grading design, linear corridor modeling, earthwork calculations, and pipe network design. The software includes plans preparation and production tools and quantity takeoff analysis and is compatible with a wide range of *AutoDesk* infrastructure design software.

Underlying Theories

In the 2009 ASEE paper (Caldwell et. al.)¹ it was proposed that some of the underlying challenges of teaching information technologies is that students must develop in all three of the domains of Bloom’s Taxonomies¹⁵⁻¹⁹:

- Cognitive: of, relating to, being, or involving conscious intellectual activity.
- Affective: relating to, arising from, or influencing feelings or emotions.
- Psychomotor: of or relating to motor action directly proceeding from mental activity.

In particular students must develop an understanding of the software (cognitive), must learn to appreciate the software’s capabilities (affective), and must develop sufficient eye-hand coordination and response mechanisms to manipulate the software (psychomotor). It is hypothesized that students must achieve some level of development in all three domains to meet the expectations of *BOK2* for Outcome 10.

In the 2011 ASEE paper (Toth et. al.)² it was proposed that in addition to the multi-domain issue, learning styles could be compounding factor in the challenges associated with teaching information technologies. Learning styles are an important consideration for all teaching environments, but compounding with the multi-domain issues – learning styles may warrant even more consideration in teaching information technology. The authors considered Felder’s Learning Styles Theory in this process because of their exposure to this theory in American Society of Civil Engineer’s Excellence in Civil Engineering Education (ExCEED) Teaching Workshop²⁰ and because of their belief it was widely appreciated across the discipline. Felder’s original Learning Style Theory considers two styles across five dimensions²¹⁻²⁵:

Table 1. Felder’s Learning Styles Theory

| Dimension | Learning Style | |
|------------------|-----------------------|------------|
| Perception | Sensory | Intuitive |
| Input | Visual | Verbal |
| Organization | Inductive | Deductive |
| Processing | Active | Reflective |
| Understanding | Sequential | Global |

It is the consideration of learning styles and the assessment associated with that consideration that is the focus of this paper and presented in what follows.

Learning Styles Survey Results and Application

The learning styles survey was administered to the 51 students enrolled in CE390 in the fall of 2012 prior to the first lesson of the semester. Students completed the survey using an online web-based tool developed and made available by Dr. Richard Felder and Barbara Soloman at NC State University (<http://www.engr.ncsu.edu/learningstyles/ilsweb.html>). The students printed their numerical results and submitted a printed copy to the authors. The results of the survey indicate the following for the students in CE390 in Fall 2012 based upon Felder and Spurlin's descriptions of the different dimensions²⁶:

- The students are fairly well balanced between sensory and intuitive learning styles. The sensing style is the concrete and practical thinker orientated towards facts and procedures. The intuitive style is the more abstract and innovative thinker orientated towards theories and underlying meanings. It is not uncommon to see a balance in this dimension among engineering students.
- The students have a moderate preference for sequential versus global learning styles. The sequential style is linear with small incremental steps and the global is holistic with large leaps in learning. Again, it is common for engineering students to have a moderate preference for sequential learning.
- The students have a moderate preference for active versus reflective learning styles. The active style is associated with learning by doing and group work. The reflective style is more associated with an individual work. Again, it is common for engineering students to have a moderate preference for active learning.
- The students have the strongest preference for visual versus verbal learning styles. The visual learner prefers the visual representation of material. The verbal learner prefers the written and spoken explanations.

As a result of the learning styles survey, several changes were implemented in CE390 in fall of 2012. To address the balanced sensory and intuitive learning styles, and the moderately preferred sequential versus global learning styles, the instructors included broader discussions and information of the underlying theories for the engineering design project, and wider global impact of the design process in the project. These discussions and information were integrated into the traditional classroom experiences and embedded into the learning path for the *Civil3D* software. With respect to the active and reflective learning styles, the instructors continued to provide both group and individual learning opportunities throughout the course. However, it was recognized that the engineering design project was predominately a group project and those students with reflective learning style may not fully appreciate the experience. The most significant change was implemented to address the strongest preference for visual learning style. In previous years, the primary learning path for *Civil3D* was static screen-shot tutorials. Based on the recommendations in the 2011 ASEE paper (Toth et. al.)² and the learning styles survey results, a set of short instructor created video tutorials were developed to parallel the static screen-shot tutorials. Additionally, a set of longer multi-part videos were identified as available through *AutoDesk*. Assessment of the student's preference for these tutorials will be discussed in what follows

Assessment of Student's Preference for Tutorials

There were five specific lessons in the computer lab where students were required to learn particular elements of *Civil3D*. The five lesson topics were as follows:

- Grading – Grading of buildings including grading objects, grading groups, and earthwork calculation and optimization.
- Roads I and II – Create a roadway alignment, profile and assemblies for a corridor model.
- Plans Development – Generate and refine corridor models as part of site grading plan to include intersections and earthwork estimates. Prepare and print production drawings of site design using view frames, labels, and annotation features.
- Stormwater – Conduct a pre and post-development hydrologic analysis of digital terrain model to include catchments using the rationale method and design a drainage pipe network using Hydraflow to determine maximum flow and velocity in each pipe and at the outlet

For each lesson, students were provided with the opportunity to use the static screen-shot tutorial or video tutorials or a combination of static and video. The video tutorials available to the students were both instructor created and those available through *AutoDesk*. The students were then surveyed upon completion of the lesson to report which they used for their individual learning path. The results for the 51 students were as follows:

Table 2. Student Tutorial Preference

| Lesson Topic | Static Tutorial | Video Tutorials | Static + Video |
|-------------------|-----------------|-----------------|----------------|
| Grading | 15% | 75% | 10% |
| Roads I | 5% | 81% | 14% |
| Roads II | 8% | 75% | 17% |
| Plans Development | 7% | 63% | 30% |
| Stormwater | 19% | 49% | 42% |

The results of the survey indicate a strong preference for the video tutorials. The authors believed that the student's preference correlated appropriately with the learning styles survey results. The impact on the engineering design project will now be discussed.

Impact on the Engineering Design Project

There were two embedded indicators within the engineering design project submission to assess the effectiveness of the *Civil3D* instruction^{10,11}. The preliminary grading plan and storm water drainage plan, each worth 25% of the final grade for a combined 50% of the engineering design project grade. The students organized into groups of two to three students each for the EDP providing a total of 18 groups in the fall of 2012. For comparison sake, the results of 17 groups from the fall of 2011 engineering design project are shown in the table. A nearly identical project was used in the fall of 2011 along with the same *Civil3D* software.

Table 3. Grades for Engineering Design Project

| Embedded Indicators | 2011 | | | 2012 | | |
|---------------------|-------|-------------|-------|-------|-------------|-------|
| | n_1 | \bar{x}_1 | s_1 | n_2 | \bar{x}_2 | s_2 |
| Grading Plan | 17 | 89.7 | 6.5 | 18 | 80.6 | 11.2 |
| Stormwater Plan | 17 | 87.8 | 6.8 | 18 | 71.3 | 12.5 |

n = sample size, \bar{x} = mean, and s = standard deviation

The results appear to show a drop in graded performance on the embedded indicators. A statistical t-test analysis²⁷ was conducted to confirm the change in performance. Assuming that the population distributions are normal and the standard deviations ($\sigma_1 = \sigma_2$) are approximately identical (+/- factor of 2), the null hypothesis is that the means are identical ($\bar{x}_1 - \bar{x}_2 = 0$).

Comparing the EDP Grading Plans from 2011 and 2012

Pooled estimate of the σ^2 is determined as follows:

$$s_p^2 = \left(\frac{n_1 - 1}{n_1 + n_2 - 2} \right) s_1^2 + \left(\frac{n_2 - 1}{n_1 + n_2 - 2} \right) s_2^2 \quad \text{EQN 1}$$

$$s_p^2 = \left(\frac{17 - 1}{17 + 18 - 2} \right) (6.5)^2 + \left(\frac{18 - 1}{17 + 18 - 2} \right) (11.2)^2$$

$$s_p^2 = 85.11$$

The t -distribution value is determined as follows:

$$t = \frac{\bar{x}_1 - \bar{x}_2 - 0}{\sqrt{s_p^2 \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}} \quad \text{EQN 2}$$

$$t = \frac{89.7 - 80.6 - 0}{\sqrt{85.11 \left(\frac{1}{17} + \frac{1}{18} \right)}}$$

$$t = 2.92$$

The rejection region is determined as follows:

$$\text{degrees of freedom} = n_1 + n_2 - 2 = 17 + 18 - 2 = 33 \quad \text{EQN 3}$$

The two-tailed rejection region for $\alpha = 0.05$ is ± 2.04 (Table IV in Devore and Peck)²⁷

Therefore, because 2.83 is greater than 2.04, the null hypothesis is rejected and there is a 95% confidence that the student engineering design project grading plan performance differed from 2011 to 2012.

Similar calculations for the stormwater plan reveal a t-distribution value of 4.81, which also results in rejecting the null hypothesis; that is, there is a 95% confidence that the student engineering design project stormwater plan performance differed from 2011 to 2012.

Discussion of Results

The instructors were concerned with the downturn in performance on the engineering design project following the effort to create a learning path aligned with the student's predominate learning styles. The overall hypothesis for the instructors was that the students would perform better on the specific *Civil3D* engineering design project deliverables if they were afforded the opportunity to learn *Civil3D* in their preferred tutorial mode. The authors do recognize that the engineering design project performance on the two embedded indicators should not be grossly taken as the only indicator of student learning associated with *Civil3D*. Several other factors were considered course-wide: student average time spent out-of-class on course material, term end exam results, incoming and outgoing GPAs, and instructor continuity. Additionally, two and EDP-specific factors were considered: student average time spent on the EDP per lesson and overall EDP scores.

Students were required to record their time spent on the course material to include the engineering design project. The average time spent out-of-class on course material throughout the term was nearly identical from 2011 (60 min) versus 2012 (59 minutes). Similarly, the term end exam results were nearly identical from 2011 (89%) versus 2012 (88%). The average GPA of the incoming students to the course did differ a bit from 2011 (3.32 on a 4 point scale) versus 2012 (3.26); however, the average outgoing reversed the trend from 2011 (3.49) versus 2012 (3.56). There was one difference in instructors from 2011 versus 2012, but the overall program manager for the course has remained constant since 2008. In summary, there was not any significant indication that the student population was significantly different from 2011 to 2012, nor that the instructor influence significantly changed.

The EDP-specific factors did correlate with the downturn in performance as observed in the two *Civil3D* embedded indicators. The student average time spent on the EDP per lesson dropped from 88 minutes per lesson in 2011 to 64 minutes per lesson in 2012. Overall, the overall EDP scores dropped from an average of 91.0% in 2011 to 81.6% in 2012. These EDP-specific support the possibility that the 2012 students just did not fully engage in the EDP as much as the 2011 students, and as a result the EDP grades decreased.

Conclusions

This paper discussed the results considering learning styles in the continuing efforts to improve the learning and teaching of a site design software package in the Civil Engineer program at the United States Military Academy. The results are an extension of two previously published papers (2009, Caldwell et. al.)¹ and (2011, Toth et. al.)². Unfortunately, the end-state of the work presented herein poses more questions than answers. Specifically, why did student performance appear to decrease on an engineering design project associated with the site design software when students were afforded the opportunity to learn the software via tutorials that appeared to correlate with their predominate learning style?

As result of the work presented in this paper, the following recommendations have been identified:

- Continue the research for another year to gather additional data to determine if the 2012 data is the start of a downward trend or is an aberration in the expected results.
- Continue to conduct the learning styles survey at the beginning of the term to catalog the learning styles of the students in CE390.
- Continue to consider the learning styles survey in the evolution of the *Civil3D* learning path in the course in support of the engineering design project.
- Develop better rubrics to assess student learning of *Civil3D*. Given the author's belief that learning information technology is multi-domain issue, such rubrics will be a challenge to develop, but worth the effort to develop.

The modern civilization will continue to develop at an exponential rate and the civil engineering profession must keep pace if we are to influence and lead that development. Mastery of information technology tools is essential for contemporary civil engineers, and the continued efforts as presented in this paper are instrumental in educating and inspiring future engineers.

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