
AC 2012-3554: CONTINUED ASSESSMENT OF INFORMATION TECHNOLOGY SOFTWARE INTEGRATION IN A CIVIL ENGINEERING PROGRAM

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Integration of Information Technology Software in a Civil Engineering Program – A Follow-Up

Abstract

Aptitude and skills in information technology remain critical in the Civil Engineering profession. Recognizing this, many universities include the development of information technology knowledge in their vision and goals, as well as their ABET outcomes and objectives. The Civil Engineering program at the United States Military Academy (USMA) is one such university. Since 2007, the program has included industry-leading software from *Autodesk* and *Bentley*. The software has been introduced in a site design course, used in follow-on courses, and integrated into the program's capstone course. Because of USMA's commitment to the development of cognitive, affective, and psychomotor skills with information technology, there has been a continuous study on the numerous and unique challenges associated with integrating such technologies into their courses and programs. An initial report provided a synopsis of efforts over the initial three semester's time (2007-2008) and this paper will report on the follow-on study. Further assessment, new approaches, and a comparison of methods will be discussed all using the same framework of three student development domains: cognitive, affective, and psychomotor. In so doing this new study will serve as a follow-up discussion on how the Civil Engineering Program at USMA continues to meet these challenges and how the solutions can be applied in others programs.

Introduction

The purpose of this paper is to discuss the continuing efforts to overcome the obstacles associated with teaching Civil Engineering software packages at the United States Military Academy as a follow-up to a 2009 ASEE Paper by the second author with Caldwell et. al, *Integration of Information Technology Software in a Civil Engineering Program*¹. The paper includes discussing the motivation for the integration of such software into a civil engineering program, supporting theories, program and course background, assessment and analysis of current efforts, and recommendations for future work.

Our profession demands civil engineers with 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)*², which references Outcome 3k of ABET Inc. *Proposed Criteria for Accrediting Engineering Program*³. 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)⁴, Clough (2000)⁵, and Bordogna (1998)⁶. The specific obstacles to meeting these needs were identified by Grigg et. al. (2005)⁴ and confirmed by the second author with Caldwell et. al. ¹:

- 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.

Theories

In the 2009 ASEE paper, 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 Taxonomies⁷⁻¹¹:

- 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 an effort to overcome the obstacles, one of the recommendations in the 2009 ASEE paper was to improve the software tutorials used to further develop the students cognitive ability and the student's appreciation of the power of the software. This was a main effort since 2009, and will be discussed herein. Throughout the tutorial development it was realized that to be effective they must also address different learning styles. This was not a surprise to the authors, but was not fully considered in the tutorial development process. The authors considered Felder's Learning Styles Theory in this process because of their exposure to this theory in ExCEED¹² and because of their belief it was widely appreciated across the discipline. Felder's original Learning Style Theory considers two styles across five dimensions¹³⁻¹⁷:

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

In the analysis of the assessment and analysis of current efforts, the learning styles will be considered by the authors.

Civil Engineering Program, United States Military Academy

The mission of the United States Military Academy (USMA) has evolved since the institution's inception in 1802¹⁸:

To educate, train, and inspire the Corps of Students 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 officer in the United States Army.

The Department of Civil and Mechanical Engineering is one of thirteen academic departments at the Academy and is ABET accredited. The mission of the Department of Civil and Mechanical Engineering parallels the Academy's mission, while focusing on educating and inspiring students in the fields of civil and mechanical engineering¹⁹:

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 United States Army 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^{20, 21}. One of the primary embedded indicators is the effective use of software in engineering problems and design projects.

CE390: Site Civil Engineering Design

CE390 Site Civil Engineering Design 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 as well as review the work of others. Proper site selection and engineering have a significant impact on the economics of a project and the long term utility of a constructed facility. 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 statements²². 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) construction²³. Course content is taught using traditional classroom instruction, homework problems, exams, and a major engineer design project (EDP) in groups. The EDP is a real scenario based on an ongoing or upcoming land development project by the Department of Public Works (DPW) at the United States Military Academy. The students receive a project proposal from an owner (DPW) and then work through the schematic design phase of land development. The EDP for the fall 2011 term 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 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.

Background: CE390 Design Software Selection

Since 2007 the USMA Civil Engineering program used *PowerCivil*, a civil engineering modeling software package from *Bentley Systems Inc*, in CE390. *Bentley's* educational license and direct support for training and program integration coupled with the widespread use of *MicroStation* (the underlying computer-aided-drawing platform for *PowerCivil*) in the US Army Corps of Engineers led to their selection initially. However, a recent assessment of *AutoCAD Civil 3D* determined their educational license was equally attractive fiscally, was widely used in the profession, and offered several advantages over *PowerCivil*. *Civil 3D* is a comprehensive design solution 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. Starting Fall 2011 term the USMA Civil Engineering Program switched to *AutoCAD Civil 3D* provided by *Autodesk*. The advantages offered by *Autodesk*, and thus the reasons for the switch were threefold and paired with the three obstacles of integrating information technology outlined above.

Faculty expertise continues to be an obstacle to integration of civil engineering software. Often the instructor is asked to teach a software package with which they have no prior experience. The instructor then must set aside research and course preparation tasks and dedicate time to learning the software. Additionally, if the software is not yet part of the curriculum the instructor has the added task of developing a learning path for the course that synchronizes with the workflow of the software. The two most critical learning support resources for the faculty learning a software package are a robust set of factory tutorials and a subject matter expert (SME). Faculty attempting to learn the software will rely heavily on factory-developed tutorials to provide them with a strong working knowledge of the program. These tutorials must be clear and contain an appropriate level of depth. An SME from the software development side is crucial to help work through difficult conceptual areas. Furthermore, once familiar with the unique constraints of the curriculum and being intricately familiar with the software, the SME can propose a learning path that best matches the program workflow. Progressing from planning to execution; once the SME helps customize the learning path for a course they became a valuable asset in troubleshooting problems (syntax errors, software nuances, etc.). Problems of this nature inevitably surface when students are working with a software package for the first time. To best leverage the SME *Civil 3D* included an automated error reporting procedure. Once a student encountered an issue due to user or program error *Civil 3D* generated an error message that was routed to the SME and individually tagged. This enabled the instructor to focus on lesson content and reference the SME automatically on technical issues outside faculty expertise.

The second obstacle with integrating a software package in an engineering course is the software complexity and the associated amount of time students require with the software to become proficient enough to accomplish the above-specified site civil design tasks. Each software program by-design has an associated learning curve for users first-introduced to the software. It is difficult to identify the learning curve without experimentation. For the past five years CE390 students expressed frustration with learning *PowerCivil* within the time constraints. *PowerCivil* is a very powerful program but had a very steep learning curve for new users. In CE390 during fall terms 2009-2011, only 16 hours were available for software focused in-class instruction time. While a lesson breakdown and the details of the learning path to address the learning curve will be discussed later, 16 hours establishes a unique, in-class-learning time constraint. The authors felt it was time to experiment with another software package to determine the availability of a solution with capability similar to *Powercivil* but a less steep learning curve. The authors were encouraged by several features of *Civil 3D* that they felt could potentially reduce the time spent becoming familiar with software; enabling students to focus on designing their site earlier in the learning process. *Civil 3D* offered an intuitive interface in the form of contextualized menu ribbon of options that anticipated the user's actions based on the objects selected in model space. The Collection tree within the program provided a hierarchal collection of objects and provided a logical alternative avenue for design tasks for users with an inductive learning style¹³⁻¹⁷. Finally a simple file architecture centered on the *AutoCAD* *.dwg file made design file management very simple.

The final obstacle and thus rationale for switching to *Civil 3D* was the interoperability with other information technologies readily available and in use in curriculum. A cohesive curriculum ties material together across several courses and the most desirable software package is one that serves as a tool throughout the curriculum. Other civil engineering curriculum technologies cover such areas as geospatial information systems (GIS), hydrology, structural analysis and design, architectural rendering, and construction management. Previously in CE390 students used *Powercivil* for site civil design and then did not use the software again until the site design portion of their senior capstone design. This was due to *Powercivil*'s limited interoperability with software used in other courses. *Autodesk*'s suite of software offers a much wider variety of software interoperability. Currently there is a seamless connection with commonly-used free software such as *Google Earth* and *Google SketchUp* in addition to other *Autodesk* software such as *Revit Structure* and *NavisWorks* for structural design and construction management. The authors believe that the previously fragmented approach to harnessing IT tools in the curriculum was a missed opportunity. A software package that is used in multiple courses stands the best chance of reinforcing the connection between civil engineering disciplines as well as demonstrating the advantages in utility of information technology.

CE390: Lesson Arrangement

The lesson arrangement to teach students *Civil 3D* for term fall 2011 consisted of six one-hour lessons during normal class hours and five two-hour lab periods. All lessons and labs were held in the computer lab and focused on the use of *Civil 3D*. This was an increase of three hours from term Fall 2009 and the same scheme used in term Fall 2010. The specific breakdown for term Fall 2011 is below:

- Lab #1 (2 hours) ArcGIS to DTM – Access and manipulate terrain data and digital raster in ArcGIS and import into Civil 3D to create a Digital Terrain Model (DTM) with a dwg.
- Lesson 9 (1 hour) DTM Investigation and AutoCAD basics - Explore a DTM using *Civil 3D* analysis tools. Complete and print a conceptual site plan using CADD elements.
- Lab #2 (2 hours) Site Recon at the EDP site – Collect site data via observation and GeoExplorer Trimble GPS for use in DTM.
- Lab #3 (2 hours) Civil 3D Fundamentals – Introduction to the fundamental structure, workflow, and capabilities of civil 3D including points, surfaces, sites, parcels, and feature lines.
- Lesson 22 (1 hour) Site Grading Design – Grading of buildings including grading objects, grading groups, and earthwork calculation and optimization.
- Lesson 23 (1 hour) Site Grading Design – Roads, create an alignment, profile and assemblies for a corridor model.
- Lab #5 (2 hours) Site Grading Design and Plans Production – 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.
- Lab #6 (2 hours) Complete a Storm water Drainage design – Conduct and pre and post-development hydrologic analysis of DTM 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
- Lesson 30 (1 hour) EDP Working Session – Complete Site Grading design
- Lesson 31 (1 hour) EDP Working Session – Complete Site Road design
- Lab #7 (2 hours) EDP Working Session – Complete Corridor Models
- Lesson 33 (1 hour) EDP Working Session – Complete Storm water design

The teaching approach in previous terms used a phased crawl, walk, run developmental model.¹ The crawl phase consisted of lecture on design concepts and hand calculation. Lessons up to 19 and including 23 brought the students through the previously outlined site civil design steps. Early lessons in this block were conceptual in nature while later lessons taught hand methods for earthwork and hydrology calculations. In these lessons the students develop the base knowledge on site design and posture themselves to make sense of the modeling in the software. During the walk phase students worked through a common scenario by following self-paced PowerPoint tutorials using a two monitor set-up with the tutorial on one screen and the software running on the other. The common scenario is designed to be manageable enough to complete in class and teach the skills needed to complete the EDP. Class sessions in the walk phase began with an overview of where the students were in the design process and a summary of lesson objectives. The PowerPoint presentations provided the lesson structure and contained customized tutorials guiding the student through the steps in the software to accomplish the design task. In the run phase students applied the design concepts and software skills learned during the crawl and walk phases to complete their EDP requirements. Most of the work in the run phase was done out-of-class with the exception of five in-class work sessions. Students were expected to bring working site models to these sessions and use in-class time to refine them with the help of the instructor.

The change in modeling software also elicited an opportunity to make changes to the learning path in term Fall 2011 for several software-focused lessons as the workflow for *Civil 3D* differed

from *PowerCivil*. As per the recommendations from the 2009 study¹, most changes came in the walk phase of the learning path and were focused on creating better tutorials. Previous tutorials contained very little background information and within the first three slides students began following a series of steps that concluded with a finished design for a portion of the site. The authors were concerned that students blindly followed the steps without thinking about what they were doing. The first learning path change was to include a global overview of the software capability within the custom tutorial for that lesson. For example in the site grading tutorial, an introductory video, an explanation of the conceptual procedure *Civil 3D* uses for grading, key terminology, and typical uses of the *Civil 3D* grading tool proceed the step-by-step walkthrough to grade an object. This change is designed to elicit thought by the student on how the tutorial fits in previously learned concepts. The class time and content for these additional slides covering this material is possible in part due to the efficiency of *Civil 3D* (simply requires fewer button clicks and uses several task wizards) and the strength of the integrated tutorials menu and user guide. Additionally, fewer individual steps were included in the tutorial slides walking them through the software. The intent for less complicated tasks was to orient the student and send them in the right direction but not provide every single step so that they are just clicking buttons without thinking. Almost all of the introductory orienting material was farmed from the *Civil 3D* user's guide which is part of the *Civil 3D* help menu. Beginning each lesson with a global overview served to connect the design or modeling capability of the software package to the engineering concept covered previously in the course during a lecture lesson. Sequencing the lessons such that design concept for a particular facet (e.g. storm water, grading design, etc) is followed by *Civil 3D* material on that same facet also promoted connections between lecture objectives and tutorial objectives. These connections reinforced the convenience and design power of the software tools.

Another change to the learning path was the use of AutoCAD factory tutorials (tutorials built by the software developer and included with the program) as part of the walk phase. Factory tutorials do not suffice to cover all lesson objectives to the appropriate depth. They did cover several key concepts. Their use reduced the instructor's lesson development time and introduced the AutoCAD tutorial menu to the students as a learning material resource. The last and perhaps most beneficial change made in term Fall 2011 to the tutorials lessons during the walk phase was the incorporation of the screen capture software *Camtasia* into the learning path. Using *Camtasia* an instructor would create a video of the lesson content by recording the execution of the tutorial (visual) all the while explaining the steps and highlighting key concepts (auditory). Throughout the semester the authors built a library of these videos for students to reference while completing their EDP requirements.

Assessment Tools

The authors used the same four assessment tools as the 2009 ASEE study to determine the effectiveness of the *Civil 3D* instruction in CE390 in the term Fall 2011: a Muddiest Point Paper conducted after lesson 18, the EDP final submission, a course-end survey conducted on the last lesson of the term (Lesson 40), and extra credit questions on the course final exam.¹ Consistency of assessment tools enabled a direct comparison with previous academic terms. Each assessment tool is discussed separately below.

1. Muddiest Point

The Muddiest Point Paper²⁴ was given to the students during lesson 18 and asked two questions pertaining to the *Civil 3D* instruction:

- 1) We have spent a majority of our lab time exploring the computer program *Civil 3D* and how it helps us as land developers and civil engineers. How effective are the self-paced tutorials in establishing a *working knowledge* of the program?
- 2) How well did the tutorials prepare you to complete your out of class assignments?

The student's feedback varied widely. Opinions on the self-paced tutorials effectiveness varied from not effective to very effective. Of the 45 students surveyed 35 stated the tutorials were effective, seven felt they were moderately effective, and three did not find them effective in their efforts to develop a working knowledge of *Civil 3D*. Those who found them effective commonly cited them as a good reference for in-class and out of class work as demonstrated by this comment, "...even if I did not remember something I knew where to look it up." Those who felt the tutorials were moderate to ineffective universally cited a lack of detailed steps. The following student comment illustrates this point well, "The tutorials are helpful but for some reason never work for me. You could possibly break some of the steps down a little further and show the symbols and what lines to hit for the more difficult steps. Use lots of pictures." This counters to a degree the sentiment behind the change in the tutorial content described earlier. Not entirely though as some students appreciated the process-based approach, "[the tutorials] did not do the same things but established a process to do what was needed," was one student's answer to question 2. The response in the negative however was large enough to warrant further consideration of the tutorial content and will be discussed in the conclusions.

Students proffered numerous recommendations; the two most helpful being requests for both video tutorials and demonstrations. One student commented, "I think it would be more effective if the first lesson you taught us the basics and then let us go on with the tutorials from there." The solution presented itself to the authors by this student's insight "I thought they [Powerpoint tutorials] were effective but video tutorials would have been better." The muddiest point paper was given very early in the walk phase and the video tutorials mentioned previously were not yet introduced. The initial plan was to use video tutorials for areas of the software with which students struggled. However, the need for demonstrations that summarize the tutorials and provide perspective on the software's capability paired with the ease with which the videos could be created encouraged the authors to incorporate the video tutorials more widely. The result was an end of class demonstration by the instructor of the broad tutorial content captured for future reference by a *Camtasia* video tutorial starting with lesson 22 – Site Grading Design.

The wide range of comments on the Muddiest Point assessment brought to the forefront the need to incorporate a variety of learning styles in the learning path to overcome the complexity of the software. Assessing previous tutorials from a learning styles lens, the authors determined the learning path focused on sequential and inductive learning styles.¹³⁻¹⁷ There was very little background information provided in previous tutorials. As evidenced by some of the above recommendations, there was a clear appeal for more material focused on the global, inductive learner. The authors' perspective up to this point had been framed by Blooms learning

dimensions. Within these dimensions repetition and time spent working through the tutorials had been our primary methods for students. Little thought had been put into the ideal learning style to which the tutorial should appeal. The addition of an introduction to each tutorial containing fundamental concepts and a broad overview of the software's capability on the topic was designed to address those students with a global and deductive learning style¹³⁻¹⁷. This change improved the student's ability to grasp the complexity of the software as long as an adequate level of detail was also included.

2. EDP Final Submission

There were two embedded indicators within the final EDP submission to assess the effectiveness of the *Civil 3D* instruction^{20,21}. The preliminary grading plan and storm water drainage plan, each worth 25% of the final grade for a combined 50% of the EDP grade. The students organized into groups of two to three students each for the EDP providing a total of 17 groups with the following results:

Table 2. Civil 3D EDP Task Grades (%) (CE390, Fall 2011)

Event	High	Low	Average	STD Deviation
Grading Plan	98.2%	78.2%	89.7%	6.5%
Storm-Water Design	98.0%	70.0%	87.8%	6.8%

Although one group was not able to complete a working storm water drainage plan (resulting in the low grade shown), the groups met the instructor's expectations and demonstrated competency in *Civil 3D*. Thus, using the current learning path students did overcome the obstacle of concern: complexity of the software. In a year-to-year comparison of these two embedded indicators, there was no noticeable difference in scores for the two events between 2009 and 2011. The drawback of this assessment tool is that it does not capture the efforts taken to complete these tasks or the student's ability to replicate the design work. Also lacking is student feedback on the tutorials and learning path overall. Furthermore, using group data does not necessarily indicate proficiency. Division of labor within groups often resulted in one student each developing the grading and Storm water plan with the third left out of the run phase of the development model. This trend, first observed in the 2009 study, remains.¹ The following two assessment techniques investigate this further.

3. Course-End Survey

During the final lesson of the course the students in CE390 completed a course-end survey. The last question on the survey asked them to rate from 1 (no confidence) to 10 (fully confident) their confidence in their abilities in the following categories:

- 1) Explain the difference between modeling (Civil 3D) and computer-aided-drafting (AutoCAD) software.
- 2) Explain the advantages of site design with Civil 3D.
- 3) Explain the general Process in Civil 3D to create a digital terrain model.
- 4) Explain the general process in Civil 3D to complete a site grading design.
- 5) Explain the general process in Civil 3D to complete a storm water drainage design.
- 6) Explain the general process in Civil 3D to complete a roadway design
- 7) Describe the difference between CAD Elements and Objects
- 8) Use Civil 3D for a site design project in the Senior Design Course (CE492)
- 9) Use Civil 3D for a site design project within five years of graduation

Six of the nine categories (all except 3, 6, and 7) are identical to the 2009 study. The results from the course end survey are provided below. The confidence level is the average for all students in each category. The authors determined a confidence index for each individual by taking the sum of their individual confidence levels for each requirement and dividing by a maximum possible of 90. The confidence index ranges from zero (no confidence) to one (fully confident). The course confidence index is an average of the 47 individual confidence indices.

Table 3. Student Confidence in Civil 3D (CE390, Fall 2011 and Fall 2009)

Study Year	Course Confidence Index	High	Low	Standard Deviation
2009	0.66	0.92	0.35	0.12
2011	0.69	0.94	0.35	0.13

Table 4. Course End-Questions and Average Student Confidence (CE390, Fall 2011 and 2009)

Confidence Level		Requirement
2009	2011	
3.5	5.84	Explain the difference between modeling (<i>Civil 3D</i>) and computer-aided-drafting (<i>AutoCAD</i>) software.
7.22	8.68	Explain the advantages of site design with <i>Civil 3D</i> .
N/A	6.98	Explain the general Process in <i>Civil 3D</i> to create a digital terrain model.
5.28	7.75	Explain the general process in <i>Civil 3D</i> to complete a site grading design.
5.61	6.55	Explain the general process in <i>Civil 3D</i> to complete a storm water drainage design.
N/A	7.82	Explain the general process in <i>Civil 3D</i> to complete a roadway design.
N/A	5.48	Describe the difference between CAD Elements and Objects
5.5	6.80	Use <i>Civil 3D</i> for a site design project in the Senior Design Course
3.67	6.50	Use <i>Civil 3D</i> for a site design project within five years of graduation

Similar to the 2009 study the course confidence index had a very wide range and a large standard deviation. The authors maintain the belief that the wide spread is a direct result of the division of labor in the EDP. With only two deliverables requiring significant use of *Civil 3D* and a majority of groups consisting of three members, there was a mismatch in “troops to task”. The result is that at least one student was left out of the run phase of the development model. While all students in the course worked through the walk phase, only the one or two students charged with building the group’s model in *Civil 3D* gained the benefits of the run phase. In light of this observed division of work, the sample population of 47 students was broken down and analyzed in groups of 15 or 16 based on their individual confidence indices.

Generally, a comparison between the 2009 study and the 2011 study shows an increase in confidence according to the index and across all categories surveyed. If the change to the tutorials was the only change made since 2009 then this increase in confidence indicates a betterment of the learning path. Other changes that may influence a direct comparison are the change in software from *Powercivil* to *Civil 3D* and the use of nine categories on the course end survey instead of the original 6 used in 2009 study. While the change in software is difficult to quantify, the effect on the confidence index due to variation in the number or questions can be isolated. In fact the 2011 study resulted in a course CI of 0.70 (higher than shown above) when comparing the six categories surveyed 2009 directly. Thus the addition of three categories does not skew the confidence index for comparison purposes.

Top Third:

Table 5. Top 1/3 Student Confidence in Civil 3D (CE390, Fall 2011 and 2009)

Study Year	Top 1/3 Confidence Index	High	Low	Standard Deviation
2009	0.79	0.92	0.73	0.05
2011	0.83	0.94	0.76	0.06

Table 6. Average Student Confidence, Top 1/3 (CE390 Fall 2011 and 2009)

Confidence Level		Requirement
2009	2011	
6.81	7.57	Explain the difference between modeling (<i>Civil 3D</i>) and computer-aided-drafting (<i>AutoCAD</i>) software.
8.61	8.86	Explain the advantages of site design with <i>Civil 3D</i> .
N/A	8.21	Explain the general Process in <i>Civil 3D</i> to create a digital terrain model.
8.14	8.86	Explain the general process in <i>Civil 3D</i> to complete a site grading design.
8.11	7.86	Explain the general process in <i>Civil 3D</i> to complete a storm water drainage design.
N/A	9.00	Explain the general process in <i>Civil 3D</i> to complete a roadway design.
N/A	7.64	Describe the difference between CAD Elements and Objects
8.03	8.43	Use <i>Civil 3D</i> for a site design project in the Senior Design Course
7.42	8.07	Use <i>Civil 3D</i> for a site design project within five years of graduation

Middle Third:

Table 7. Middle 1/3 Student Confidence in Civil 3D (CE390, Fall 2011 and 2009)

Study Year	Middle 1/3 Confidence Index	High	Low	Standard Deviation
2009	0.67	0.72	0.63	0.03
2011	0.72	0.74	0.67	0.03

Table 8. Average Student Confidence, Middle 1/3 (CE390 Fall 2011 and 2009)

Confidence Level		Requirement
2009	2011	
5.83	6.00	Explain the difference between modeling (<i>Civil 3D</i>) and computer-aided-drafting (<i>AutoCAD</i>) software.
7.71	9.13	Explain the advantages of site design with <i>Civil 3D</i> .
N/A	7.67	Explain the general Process in <i>Civil 3D</i> to create a digital terrain model.
7.33	7.93	Explain the general process in <i>Civil 3D</i> to complete a site grading design.
6.28	6.87	Explain the general process in <i>Civil 3D</i> to complete a storm water drainage design.
N/A	7.67	Explain the general process in <i>Civil 3D</i> to complete a roadway design.
N/A	5.47	Describe the difference between CAD Elements and Objects
6.89	7.13	Use <i>Civil 3D</i> for a site design project in the Senior Design Course
6.06	6.60	Use <i>Civil 3D</i> for a site design project within five years of graduation

Bottom Third:

Table 9. Bottom 1/3 Student Confidence in Civil 3D (CE390, Fall 2011 and 2009)

Study Year	Bottom 1/3 Confidence Index	High	Low	Standard Deviation
2009	0.51	0.62	0.35	0.08
2011	0.54	0.64	0.32	0.09

Table 10. Average Student Confidence, Bottom 1/3 (CE390 Fall 2011 and 2009)

Confidence Level		Requirement
2009	2011	
3.50	4.07	Explain the difference between modeling (<i>Civil 3D</i>) and computer-aided-drafting (<i>AutoCAD</i>) software.
7.22	8.07	Explain the advantages of site design with <i>Civil 3D</i> .
N/A	5.13	Explain the general Process in <i>Civil 3D</i> to create a digital terrain model.
5.28	6.53	Explain the general process in <i>Civil 3D</i> to complete a site grading design.
5.61	5.00	Explain the general process in <i>Civil 3D</i> to complete a storm water drainage design.
N/A	6.87	Explain the general process in <i>Civil 3D</i> to complete a roadway design.
N/A	3.47	Describe the difference between CAD Elements and Objects
5.50	4.93	Use <i>Civil 3D</i> for a site design project in the Senior Design Course
3.67	4.93	Use <i>Civil 3D</i> for a site design project within five years of graduation

All categories surveyed in 2011 showed improved student confidence over 2009 with the exception of storm water drainage design for the top and bottom third and the bottom third's confidence in use of the software during their senior capstone design project. Of particular note a strong majority of students surveyed stated an increased confidence in their use of software in the future for their design course and after graduation. In light of the changes made to the learning path these were encouraging results. The authors believe this is a direct result of both focusing student development in the cognitive, psychomotor and affective domain and a growing effort to customize the learning path to a wider variety of learning styles. Notably the addition of global material at the beginning and end of each lesson provided perspective early in the cognitive learning process. Students would start the sequential portion of the tutorials with a better understanding of the final goal. Video recorded demonstrations material added at the beginning and end oriented the student to the software's modeling process and design language; clearly showing the use of the software's design capabilities to accomplish site design concepts. With the use of these videos the authors sought to address a wider range of learning styles by adding sensory elements in the perception dimension and adding verbal to the already visual nature of the tutorials for the input dimension.¹³⁻¹⁷ In addition to promoting development in the cognitive domain, the videos elicited significant development in the affective domain. A demonstration video less than ten minutes in length provides an "awe factor." Viewing the demonstrations in class, the students observed the sequence of design steps in fairly rapid succession. The process of watching a blank design slate (digital terrain model base map) become a designed model in minutes is motivating. Demonstrations of this nature reduced the intimidating complexity of the software and instilled confidence. One student's comment on the end of course survey typified many, "I liked gaining experience with *AutoCAD*... the *AutoCAD* tutorials, while very intricate, take way too long to read and then do everything in them. The videos speed up the learning process a lot, showing me I could do it. I learned a lot in this course." Video demonstrations (either by instructor or provided with the software) played a critical role in helping students visualize the use of the software and value it as a design tool.

Curious on students opinions of video tutorials relative to the other methods of instruction in use, a question was asked in a subsequent on-line course end survey requesting students rank order the following four methods most to least helpful for learning how to use Civil 3D.

- 1) Self-paced PowerPoint tutorials
- 2) Self-discovery learning
- 3) Instructor generated videos
- 4) AutoCAD developed factory tutorials

Of the 40 students that completed the survey, 82% ranked Instructor generated videos first. The usefulness of video tutorials was also initially assessed during the course end survey. Students were asked to rate the helpfulness 1(No help) to 10(Extremely helpful) of the videos in developing a working knowledge of the software. Universally the videos were considered helpful with an average response of 9.33. No single response was below a 9.

Within 2011 there is a marked difference between grading design of buildings and roads and storm water drainage design. The authors believe this is a result of the software's use of the add-in storm water drainage network analysis program *Storm Sewers Hydraflow*. The export of *Civil 3D* pipe networks to *Hydraflow* was not seamless. Once in *Hydraflow* the workflow was less clear, the program was at times frustratingly finicky, and factory tutorials were not available. All of these would contribute to student's feeling less confident in future storm water design use. The more difficult workflow encountered here highlights a specific need to customize the learning path to a variety of learning styles. There is a clear need for more detailed tutorials in future semesters to promote understanding of the software in the cognitive domain and build the students baseline confidence in completing the design task⁷⁻¹⁰. One student commented on the storm water drainage design, "Doing self guided tutorials were sometimes incredible frustrating. There is no feeling like spending 15 minutes look for a button on a computer screen and somehow not being able to find it." Here is a reminder that the complexity of certain tasks still requires detailed step-by-step tutorials. The need to provide steps for sequential, inductive learners remains important in developing working knowledge of the software. The granularity of the steps becomes critical to provide the immediate gratification of having figured a step out. As a student progresses, successfully completing individual steps, they build momentum into the next task. As opposed to a tutorial where a student flounders in the task with too few guiding steps, a tutorial that maintains momentum provides a sense of accomplishment, inspiring further use of the software.

4. Final Exam Extra Credit Questions

The course final exam included four questions from the course-end survey for extra credit. The questions and possible points were:

- (5 points) Explain the difference between modeling (*Civil 3D*) and computer-aided-drafting (AutoCAD) software.
- (5 points) Explain the advantages of site design with *Civil 3D*.
- (5 points) Explain the general process in *Civil 3D* to complete a storm water drainage design.
- (5 points) Explain the general process in *Civil 3D* to complete a site grading design.

The point values associated with each question were not advertised to avoid encouraging the students to weight their effort. Additionally all students left the exam before the time was up, which indicates they all had sufficient time to answer the questions. Therefore if a question was left blank it was recorded as a zero for the purposes of our sample data. The individual proficiency level was determined by taking the individual's average score for a question and converting it to a 10 point scale for comparison to the confidence level from the course end survey section above. For example, if a student scored a 2 on the first question their proficiency level would be $(2/5)*10 = 4.0$. The individual data was then averaged to obtain the proficiency level of each sample group for a particular question. For the same reasons described above the students were divided into three sample groups (top, middle, bottom third) according to the individual proficiency indices. The proficiency indices were the sum of the individual's proficiency levels divided by a total possible of 40.

Top Third:

Table 11. Top 1/3 Student Proficiency in Civil 3D (CE390, Fall 2011 and 2009)

Study Year	Top 1/3 Proficiency Index	High	Low	Standard Deviation
2009	0.83	1	0.73	0.08
2011	0.86	1	0.70	0.11

Table 12. Average Student Proficiency, Top 1/3 (CE390, Fall 2011 and 2009)

Proficiency Level		Requirement
2009	2011	
8.19	8.00	Explain the difference between modeling (<i>Civil 3D</i>) and computer-aided-drafting (<i>AutoCAD</i>) software.
7.78	8.67	Explain the advantages of site design with <i>Civil 3D</i> .
8.00	9.07	Explain the general process in <i>Civil 3D</i> to complete a storm water drainage design.
9.08	8.53	Explain the general process in <i>Civil 3D</i> to complete a site grading design.

Middle Third:

Table 13. Middle 1/3 Student Proficiency in Civil 3D (CE390, Fall 2011 and 2009)

Study Year	Middle 1/3 Proficiency Index	High	Low	Standard Deviation
2009	0.65	0.73	0.6	0.04
2011	0.59	0.70	0.45	0.10

Table 14. Average Student Proficiency, Middle 1/3 (CE390, Fall 2011 and 2009)

Proficiency Level		Requirement
2009	2011	
5.42	4.50	Explain the difference between modeling (<i>Civil 3D</i>) and computer-aided-drafting (<i>AutoCAD</i>) software.
6.25	6.25	Explain the advantages of site design with <i>Civil 3D</i> .
6.58	6.88	Explain the general process in <i>Civil 3D</i> to complete a storm water drainage design.
7.58	5.88	Explain the general process in <i>Civil 3D</i> to complete a site grading design.

Bottom Third:

Table 15. Bottom 1/3 Student Proficiency in Civil 3D (CE390, Fall 2011 and 2009)

Study Year	Bottom 1/3 Proficiency Index	High	Low	Standard Deviation
2009	0.44	0.60	0	0.15
2011	0.25	0.40	0	0.14

Table 16. Average Student Proficiency, Bottom 1/3 (CE390, Fall 2011 and 2009)

Proficiency Level		Requirement
2009	2011	
2.92	1.13	Explain the difference between modeling (<i>Civil 3D</i>) and computer-aided-drafting (<i>AutoCAD</i>) software.
4.31	5.13	Explain the advantages of site design with <i>Civil 3D</i> .
5.75	2.63	Explain the general process in <i>Civil 3D</i> to complete a storm water drainage design.
4.75	1.00	Explain the general process in <i>Civil 3D</i> to complete a site grading design.

Within the 2011 study the top third demonstrated a proficiency greater than their expressed confidence in the use of *Civil 3D* for site design. Surprisingly this was due to their demonstrated understanding of storm water drainage design in *Civil 3D*, the design task they expressed the least confidence in during the course end survey. The authors believe that while frustration with the storm water analysis software and completion of individual tasks eroded their confidence, the students in the top third understood the overall design process.

The middle and bottom third performed well below their self-expressed confidence level across all questions. Similar to the 2009 study, the dramatic drop in proficiency in the middle and bottom third reinforces the impact of the division of labor on the EDP Civil 3D tasks between group members has on the students learning of the software.

Comparison with the 2009 study results in similar if not slightly better proficiency of the top third in 2011 with significantly decreased proficiency for the middle and bottom thirds. Granularity associated with a difference in point values between 2009 and 2011 (the first two

questions were worth just three points in 2009) may account for some of the difference. As do the differences in applying the somewhat subjective set of grading criteria used for grading the questions between the two studies (a different instructor graded the exams in 2009 than in 2011). However, the significant drop in proficiency for the middle and lower third warrants further study. A recommendation from the 2009 study was to ensure every student in each group is actively engaged completing the EDP by completing modeling tasks in the software. This would ensure that all students would participate in the run phase of the development model. At present, the authors have not been able to develop a solution to this dilemma within the course constraints and that satisfies the course objectives. So the question remains on how best to address the students in the lower third. The method the authors are currently pursuing is to improve the walk phase tutorials so as to bring all students to an acceptable level of working knowledge even before the run phase. Group members who work on the EDP become that much well-versed in the software. Ultimately, the authors' goal is to improve the walk tutorials such that all students gain such an appreciation for the software's capacity that they are motivated to work on the site design and continue use of the software in the run phase. This will rely heavily on intrinsic motivation. The author's acknowledge that this goal may not be achievable for all students, especially those technologically challenged or particularly difficult to motivate.

Generally, the authors were pleased with the progress on overcoming the stated three obstacles to integrating information technology into a civil engineering program. This was the first year *Civil 3D* was used as the tool for site design. Experience demonstrates that the integration of new software in CE390 can take two to three terms of instruction to refine. With 80% of the course rating themselves as 60% confident or greater in their abilities to use the software for site design and 55% demonstrating 60% or better proficiency the authors believe we reached a reasonable level of understanding and application for the use of a professional civil engineering modeling software package in an undergraduate level course.

Conclusions

The paper discussed the continuing efforts to overcome the obstacles associated with teaching Civil Engineering software packages at the United States Military Academy. Future work has been identified as follows:

- Conduct a learning styles survey at the beginning of the term to catalog the learning styles of the students in CE390 and develop a new assessment tool to assess the effectiveness of the current learning path
- Experiment and assess the sequencing of methods within the learning path. The current approach is to create a content sandwich consisting of global orienting material at the beginning of the lesson, summarizing and capability demonstration via video tutorials at the end with the middle of the lesson consisting of step-by-step tutorials. The author's believe that student comments such as the following hint at future improvements, "I liked gaining experience with AutoCad, but you should use the instructor videos first." and "The [EDP] was a great learning experience, but went well over the 2 hr window. I think the learning curve would increase tremendously if [instructor] did a run through of the lab lesson beforehand (typically done at the end), in order to weed out all the small tutorials options that, really, we don't need to know."

Several recommendations are offered to programs facing similar challenges:

- Develop and maintain a complete library of videos. Videos designed for orientation/demonstration (average length 5 minutes, 10 minutes maximum to retain student's attention) and step-by-step instruction (10-20 minutes in length) are both beneficial. A fairly fast tempo and specificity of terminology throughout are important. Creating these videos will take significantly less time to complete than the PowerPoint slide, still-picture based tutorials.
- The tutorials within learning path should include material addressed for global, deductive learners as well as sequential, inductive learners. This variety of learning styles will build the most capacity in the largest number of students.

Building on the 2009 ASEE study, the authors hoped to reduce the complexity of a professional civil engineering software package by improving the student learning path and positively contribute to the civil engineering profession.

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