# AC 2009-1059: INTEGRATION OF INFORMATION-TECHNOLOGY SOFTWARE IN A CIVIL ENGINEERING PROGRAM

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# Integration of Information Technology Software in a
# Civil Engineering Program

## Abstract

The Civil Engineering profession demands rapidly advancing skills in information technology. As a result, many universities include the development of information technology knowledge in their vision and goals, and ABET outcomes and objectives. There are many challenges associated with integrating such technologies in courses and programs. Underlying these challenges is the realization that student development in these areas is likely to encompass all three commonly accepted domains of development; the cognitive, affective, and psychomotor domains. Furthermore, such technologies are advancing at a rate faster than the faculty can develop the skills required to teach to the students. As such, by the time faculty develop sufficient knowledge, appreciation and physical skills to use the technologies, the technologies have advanced to the next level. This paper will discuss how the Civil Engineering program at the United States Military Academy has met these challenges, assessed them, and applied solutions.

## Introduction

The purpose of this paper is to discuss the challenges, assessments, and applied solutions associated with teaching a specific Civil Engineering software package at the United States Military Academy. The software is a state-of-the-art information technology platform. The Civil Engineering profession demands rapidly advancing skills in information technology. Such expectations are embedded 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)*[1], which references Outcome 3k of ABET Inc. *Proposed Criteria for Accrediting Engineering Program* [2]. The *BOK2 Levels of Achievement Subcommittee* recommends that civil engineers who have earned a bachelorette 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 to[2]:

- *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.

Others that have recognized these needs with respect to the Civil Engineering profession include Grigg et. al. (2005)[3], Clough (2000)[4], and Bordogna (1998)[5]. Furthermore, Grigg et. al. (2005)[3] reported on the obstacles to educators in trying to meet these needs that evolved from research at Colorado State University sponsored by the National Science Foundation. The obstacles included limited faculty capacity to maintain pace with the technologies, complexities and cost of the technologies, and the difficulty of integrating the technologies across a program rather than a one-class exposure. These obstacles were also observed at the United States Military Academy, and are addressed in this paper.

**Multi-Domain Learning Challenge**

The authors propose that the underlying challenge of teaching information technologies is that students must develop in all three of the domains of Bloom's Taxonomy. Bloom's Taxonomy is the seminal work of the 1950's educational committee chaired by Benjamin Bloom. The committee established a set of taxonomies in three domains of learning: cognitive, affective and psychomotor. The cognitive domain taxonomy is widely accepted in many fields and has been identified as, "arguably one of the most influential education monographs of the past half century."[6] The taxonomies are a language that describes the progressive development of an individual in each domain and are defined as follows[7]:

- 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.

A set of development levels for each domain are shown in Table 1 based on work by Bloom (1956)[8], Krathwohl et. al. (1973)[9], and Simpson (1972)[10], respectively. Each column shows the levels in each domain, from the simple at the top, to the more complex at the bottom.

Table 1. Domain Levels

| Cognitive Domain[8] | Affective Domain[9] | Psychomotor Domain[10] |
|---|---|---|
| Knowledge | Receiving | Perception |
| Comprehension | Responding | Set |
| Application | Valuing | Guided Response |
| Analysis | Organization | Mechanism |
| Synthesis | Characterization by a | Complex Overt Response |
| Evaluation | Value Complex | Adaptation |
| | | Origination |

The focus of this paper is with respect to a particular software package, which will be discussed in more detail later. With respect to the software, 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 cognitive domain, it is proposed that students must achieve the application level of Civil Engineering Information Technology software. This is in synch with the same level of expectation for the *BOK2* Outcome 10. To achieve this level, students must develop basic knowledge of a particular software package and comprehend the applications of the software. Furthermore, this knowledge and comprehension must be effectively applied while using the software.

In the affective domain, it is proposed that students must achieve the valuing level, which corresponds loosely to the application level in the cognitive domain.[11, 12] At this level the student voluntarily recognizes the benefits of learning the software and is willing to sacrifice to meet the challenge of learning the software.

In the psychomotor domain, it is proposed that students should achieve at least the guided response level and potentially the mechanism level. The guided response level indicates students would use the software with step-by-step instructions. The next level, mechanism, would require the students to apply learned actions to a new situation. As such, development of some complex or limited use software commands and syntax would suffice to be guided, whereas some more common or repetitive commands should be learned at the mechanism level.

**Civil Engineering Program, United States Military Academy**

The mission of the United States Military Academy (USMA) has evolved since the institution's inception in 1802[13]:

***To educate, train, and inspire the Corps of Cadets 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 11 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 engineering[14]:

***To educate cadets 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 cadets 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[15, 16]. One of the primary embedded indicators is the effective use of software in engineering problems and design projects.

In the Fall of 2007 the USMA Civil Engineering program initiated the use of a new software program in several courses. The software is *PowerCivil,* provided by *Bentley Systems Inc..* The stand-alone program is a comprehensive design solution for site modeling, land development, and planning. It is a multidiscipline tool that provides integrated capabilities for survey, graphical coordinate geometry, digital terrain modeling, site grading and design, street design, water and sewer design, and storm water drainage design. The toolset supports plans preparation, plan sheet generation, and volume/material quantity calculation for a wide range of projects,

such as commercial and residential site development, and civil infrastructure projects. *MicroStation* is the underlying computer-aided-drawing platform. The competitive product from *AutoDesk* is *Civil3D*. The *PowerCivil* package was chosen over *Civil3D* because *MicroStation* is licensed for use in the US Army Corps of Engineers, which many of the USMA CIVIL ENGINEERING program graduates elect as the branch to serve as officers. Furthermore, *Bentley* was attractively priced for academic use and provided direct support for training and program integration. *PowerCivil* was used in CE390, Site Civil Engineering Design in the fall 2007 term and in CE492, the CIVIL ENGINEERING program's capstone course in the spring 2008 term. The assessment of the program in these courses follows.

### *PowerCivil* in CE390, Site Civil Engineering Design, Fall 2007 Term

CE 390 Site Civil Engineering Design is a site design and land development course required for all civil engineering majors in the first semester of their junior year. This course provides students the necessary background to select and develop sites for civil engineering structures as well as review the work of others. Proper site selection and engineering have a significant impact on the economics of a project and long-term utility of the constructed facility. Specifically, the course covers the skills of determining site layout and access, establishing site contour and drainage, installation of utilities, elementary surveying, creation of site models using advanced civil engineering software, and the development of environmental impact statements. The course textbook is the Dewberry Company's _Land Development Handbook,_ third edition. The course is structured around the seven steps of the land development process as outlined by Dewberry:  1) feasibility and site analysis 2) programming 3) conceptual design 4) schematic design 5) final design 6) plans submission and permitting 7) construction. In addition to traditional classroom instruction, homework problems, and exams, the students are required to complete 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 are given a project proposal from an owner (DPW) and then must work through the schematic design phase of the land development.

The EDP for the fall 2007 term was the development of a local elementary school site. The problem statement included demolition of current buildings and redesign of the site to include a new elementary school, a new middle school, playgrounds, multiple athletic fields, and the supporting parking and traffic network necessary to support the increased usage. The primary tool to accomplish the site design was the civil engineering modeling software package, *PowerCivil*. Each group was expected to use *PowerCivil* to produce a final site layout with final designs for earthwork (grading), storm water management, and transportation systems as part of the EDP final submission. CE 390 is the first course in the civil engineering program in which students work with *PowerCivil*; therefore, a considerable amount of effort was required to teach the program skills required to successfully complete the EDP. During the semester, four two-hour lab periods were focused on the use of *PowerCivil*. The first three lab sessions were designed to teach the students the program and the fourth was a working session to complete the EDP requirements.

There were only two assessment tools to determine the effectiveness of the *PowerCivil* instruction in fall 2007: The *PoweCivil* products in final EDP submissions and specific student comments on a course-end survey. As the semester progressed and the students moved further into the EDP three things became clearly evident. First, six hours of instruction on the computer program was insufficient to get the majority of the students to the desired level of proficiency. Second, the instructors did not possess the depth of knowledge in the program to properly assist the students through the problems and frustrations that arose due to their lack of proficiency. Finally, given these challenges, it became clear that the students were not going to be able to produce the expected final designs in *PowerCivil* on the EDP. Therefore, midway through the semester the choice was given to the students to either produce their final designs in *PowerCivil* or by hand. It is our assessment that in most cases the students understood the power and usefulness of the computer modeling program, but based on the decision to not use it for the EDP by some groups, it was clear that they were not confident in their own abilities.

The student feedback on the course-end survey is very telling of their perception of *PowerCivil* and the effectiveness of the instruction as well. In the course specific questions the students rated their development of CADD skills much lower than all the other skills taught in the course. This is further amplified in specific student comments:

"This course was very interesting and we learned some information that was very applicable and fun to learn. I do feel, however, that the EDP required too much use of technology. While it can be argued that you didn't need to rely on technology (*PowerCivil*) for the EDP, the reality is that if you didn't have a very good working knowledge of *PowerCivil*, you would need to spend hours upon hours of figuring out how to use it, or just as much time doing things by hand. I think that if the EDP is going to require this much use of technology, there should be more time devoted to learning the technology, not just the few lab periods that we spent. It may be necessary to implement a class on technology alone, or to change the EDP to require less knowledge of the technology. I think the EDP could have been very fun and interesting if I had not been so frustrated with *PowerCivil*."

"I think that more time should be spent in the CADD lab. That way we could take notes on the boards still but also to reinforce the lesson. For example when learning about pipe flow we could actually do an example at our computers."

"I think it is an excellent idea to do an EDP and have it be tied in to site design, however I think it should be more of a focus and everything that we learn in the class should have to do with the EDP. That way we can actually learn CAD properly instead of flying blind and having to ask instructors who aren't sure how to help with the program themselves. Overall this course was interesting but I think it needs a little tweaking to make it better."

The above comments echo the same message put forth by a good number of the students in the course. In general, they liked the challenge of the EDP but felt unequipped with the technology skills necessary to successfully complete it.

***PowerCivil* in CE492, Civil Engineering Program Capstone Course, Spring 2008 Term**

CE492 Building Systems Design is the Civil Engineering capstone design course required for all civil engineering majors in the second semester of their senior year. This course provides an opportunity for students to apply and synthesize their knowledge of structural steel design, reinforced concrete design, structural analysis, geotechnical engineering, hydrology, hydraulic engineering, construction management, site planning, and engineering economics in an open-ended, realistic, semester-long capstone design experience. Working in small groups acting as a civil engineering consultant team to an architecture firm, students follow a nine phase Engineer Design Process, commonly used in the US Army Corps of Engineers, to develop the functional requirements for a proposed project site and develop several feasible courses of action that they can then quantifiably evaluate against measurable criteria. The teams consist of a Project Manager, Structural Engineer, Geotechnical Engineer, Hydrologic Engineer, and a Construction Manager. The students have to conduct in-depth problem solving and engineering estimates to determine the best course of action. The students determine architectural schemes of the buildings on the site along with proposed structural, foundation, and site designs for the facility. Execution of the design requires extensive use of computer-based analysis and design tools. The products of this effort include a comprehensive design report, plans production of the site and facility, and several briefings to the client. The integrated design experience is augmented by formal classroom instruction in structural systems design, advanced topics in structural design, selected geotechnical and hydrologic topics, and software tutorials. This course constitutes the integrative experience for students majoring in Civil Engineering at USMA.

The EDP for CE492 in the spring 2008 term was the development of a motor pool complex. The request for proposal included the determination of the motor pool buildings' sizes, locations and appearance, the structural systems that support these buildings, and the site engineering work to support the determined site plan. The facility requirements included vehicle parking for 60 buses, 300 single unit trucks, 400 passenger cars, patron parking for 100 passenger cars, an outdoor wash facility of 2500 sf, a fuel island with two pumps and underground storage of two 5000 gallon fuel tanks, and support buildings. To help them analyze the site and develop a set of feasible solutions, the students used *PowerCivil* to determine predevelopment drainage, cut-fill volumes, slopes of proposed roads, and to identify possible locations of retention walls and post development storm water detention ponds. CE492 was the second course where students used *PowerCivil*, but their understanding of the program was minimal. Five one-hour classes and a homework tutorial were used to teach some basic *PowerCivil* skills to the students. The topics covered were basic CADD drafting skills using MicroStation, developing a Digital Terrain Model from topographic data, building site selection and grading plans, site drainage analysis and storm water system design, road design, and plans production. Each student chose to take their mid-term exam on either the *PowerCivil* or *Bentley Structural* software. The exams were very basic, and the tasks for each test were given to the students more than a week prior to the date of the exam.

The same challenges experienced in CE390 in the fall 2007 term resurfaced in CE492 in the spring 2008 term. Some of the challenges encountered during the implementation of *PowerCivil* included lack of instructor knowledge, poor training aids, student frustration with the program from prior experience in CE390, and improper software installation. The instructor designated to

teach *PowerCivil* had no CADD experience and limited time to prepare. This resulted in the instructor having to learn the program at the same time as teaching the program. An on-line tutorial program was available from the software provider, but was difficult to use for a beginner and did not match well with the proposed academic use in CE492. The software provider was contacted and access to a *PowerCivil* subject matter expert was arranged. The subject matter expert was instrumental in providing up to date tutorials, developing a learning path, responding to technical questions, and preparing videos of how to accomplish specific tasks for use in subsequent *PowerCivil* lessons. By working with the *PowerCivil* program manager, the authors finally began to learn what we did not know about the program, which allowed us to better determine how to teach it to our students.

In assessing how well *PowerCivil* helped us reach our goal to equip each student with the ability to use engineering software, four assessment tools were used: instructor feedback, results from the mid-term exam, graded site plans for the EDP project, and student course end feedback. Of the 57 students in CE492, 20 took the *PowerCivil* mid-term exam. The average was 84.4% with a high score of 99%, and a low score of 49%. The low score was a failing grade, resulting from a student who did not try to learn the software until the day before the test. There were 11 design teams, and all of the site plans were designed using *PowerCivil*. All of the design teams were able to produce readable site plans to include site construction by phase. However, the students voiced their frustration and did not like the experience of trying to learn the software from an instructor who was unfamiliar with the product.

The student feedback on the course-end survey is honest, blunt and telling of their opinion of the software and their experience with it in the course. We knew that the instructors needed training, and that our lab technicians needed to know how to properly install the software and set up the libraries. We also knew that we had to have a more cohesive program developmental plan to teach the software so that students were not learning how to use it during the capstone, but rather able to use it as a tool by the time they reach the capstone. The comments that follow are reflective of the overall tone in the student feedback:

> "Probably the worst experience from a class that I had at the academy. The expectations of this course were unreasonable. It is my feeling that the capstone course is not designed to emphasize learning a new (software) program, that is as difficult as Microstation, and be able to produce a quality product."

> "The instructors need to know the software packages much better before trying to teach them."

> "Why do I have a D in this course when I spend more time on it than any other course I am taking at the moment? I spent 25 hours on the 65% IPR only to get a B- and the fact that I have to take a TEE now because I didn't learn a CADD program that didn't work all semester and didn't apply to my job as project manager is complete BS. This class is ridiculous. I think the expectations are too high and the instructors aren't even sure what they are looking for. When we have to learn a CADD program that no one knows how to do and most people learned the night before, barely passing the test is ridiculous. Give me a break."

"For next year I would suggest only using computer programs that you are familiar with. If seems rather inefficient to use programs that you cannot answer questions about."

"Although it may have been the intent to leave this project's guidelines very broad, there are times when the instructors need to step in and give more detailed guidance. Also, it's kind of hard to expect students to be able to do something in a CAD program if the instructors themselves cannot perform that same function."

**Actions Taken**

As a result of the experiences in CE390 and CE492, several actions were taken to address the issues with integrating *PowerCivil* in the USMA Civil Engineering Program. These actions were developed with consideration for the proposed underlying challenge of developing the students across the cognitive, affective, and psychomotor domains. First, faculty training and education on the software was necessary. The faculty recognized the steep learning curve of the software and set aside significant training time in the summer of 2008 to better prepare for teaching the software. The software provider coordinated access to on-line learning systems and provided a subject-matter-expert for three days of on-site training. Second, it was decided that a set of project specific tutorials would be created to address the specific course goals with respect to the software. This approach was chosen over using "off-the-shelf" tutorials from the software provider. The decision was made to ensure the depth of coverage was limited to reasonable expectations and the students would develop their software skills along a common project, which paralleled the course classroom content. Furthermore, although expensive in time to create, the development of tutorials forced the instructors to become intimately familiar with the software. Third, extra instructors were on-hand during the lab sessions to assist students.

The three actions taken required significant resources, but it was worthwhile because of the recognized challenges associated with teaching the software. The actions were developed because they would span across all three domains. A greater knowledge of software, beginning with the instructors, helped ensure the cognitive domain expectation was met. The affective domain was addressed in the project specific tutorials, with the hypothesis that students would better value the software if they could see how it was integrated with the course classroom content and was used in their EDP project. The psychomotor domain was addressed through the development of in-depth tutorials, which guided the students through the myriad of software commands and syntaxes, and the surge of capable instructors during the training to provide a greater teacher to student ratio. Beyond these actions, it was recognized that the assessment process was lacking and also needed to be addressed.

***PowerCivil* in CE390, Site Civil Engineering Design, Fall 2008 Term**

CE390 in fall 2008 term began with the largest CIVIL ENGINEERING enrollment in over 10 years and would fully test the actions taken to more effectively develop the students' skills in *PowerCivil*. The CE 390 EDP for this term was the development of a partially developed mixed use (residential and retail) area of approximately ten acres to include a new child development center, playground, community pool, pool facility, single soccer field, and all required parking to support these facilities. The project was conducted in groups of three students each and the final

submissions included a site layout (building pads, parking lots, soccer field and pool) modeled in *PowerCivil* with preliminary earthwork calculations and a preliminary storm water drainage system with pipe sizes and an estimated peak discharge.

In order to prepare the students to use *PowerCivil* on the EDP, five one-hour lessons during normal class hours and four two-hour lab periods were held in the computer lab and focused on the use of *PowerCivil*. This was five more hours (a 60% increase) than used in CE390 in the fall 2007 term. The specific break down of the fall 2008 lessons and labs was as follows:

- Lab #1 (2 hours) Introduction to ArcGIS - Create a .dgn file with contour data in ArcGIS for use in *PowerCivil*, clip a raster in ArcGIS for use in *PowerCivil*.

- Lesson 10 (1 hour) Introduction to *PowerCivil* - Create a digital terrain model (DTM), explore a DTM using the DTM tools.

- Lab # 2 (2 hours) Site Recon at the EDP Site.

- Lesson 13 (1 hour) Complete and print a conceptual site plan - Draw CADD elements in a *PowerCivil* .dgn file, Print a .dgn file.

- Lab #3 (2 hours) Model in *PowerCivil* - Create a project, create objects, create elements and drape them on the model.

- Lesson 19 (1 hour) Complete a site grading plan in *PowerCivil* – Create a pool object, balance earthwork for an object, determine the gross earthwork for a project.

- Lab # 4 (2 hours) Site Surveying at the EDP site.

- Lesson 22 (1 hour) Complete a site hydrology plan in *PowerCivil*- Create drainage basins using the rational method, create a drainage pipe network, determine the maximum flow and velocity in each pipe and at the outlet.

- Lab #5 (2 hours) EDP Working Session - Complete the site grading and storm-water designs for the EDP.

- Lesson 27 (1 Hour) EDP Working Session.

- Lab # 6 (2 hours) EDP Working Session - Produce plans for the final EDP submission.

The planned teaching approach was a phased strategy using a crawl, walk, run developmental model. For every session up to Lesson 22 the instructional period began with an orientation to the concept and content using black boards and flow charts to demonstrate to the students what was happening "behind the scenes" in the computer program. This was the crawl phase. Students then worked through a common design scenario by following a self paced PowerPoint tutorial using a two monitor set-up with the tutorial on one screen and the program running on the other, as shown in Figure 1. A sample of the PowerPoint tutorials is shown in Figures 2a and 2b. The common scenario was designed to be a small portion of the larger EDP design. This was the walk phase. In the run phase, the students applied the skills learned in the common scenario to complete their EDP requirements. This portion was done largely on the students' own time outside of class. The last four hours of lab time were provided to answer questions, help the students successfully complete their projects, and produce the plans for inclusion in the EDP final submission. The intent was for the students to arrive at these sessions with an already working model and then apply the finishing touches to their designs. The final submission of the EDP was not a completed 100% design. The EDP ended in the schematic design phase and students were expected to complete good preliminary engineering in the areas discussed above. Prior to the *PowerCivil* instruction in Lessons 19 and 22, a traditional classroom lesson was used to teach the hand methods for earthwork and hydrology calculations, and another lesson for working the common scenario by hand. This allowed instructors to come back to these examples in the computer lessons and compare the hand calculated values to the computer values, reinforcing the accuracy and convenience of the computer program.
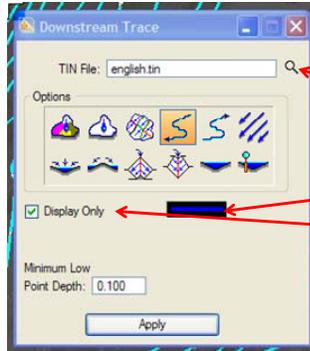


**Figure 1. Students Working on *PowerCivil* with *PowerPoint* tutorial.**

## Investigate DTM with Analysis Tools
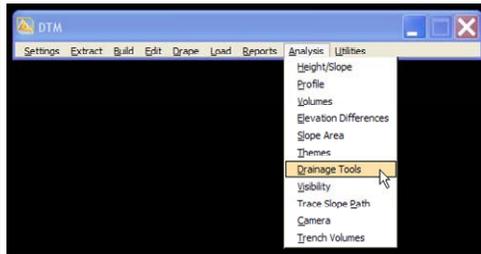
Drainage Tools

1. Select **Analysis** -> **Drainage Tools** -> **Downstream Trace**.

Input data in the pop-up Downstream Trace menu as shown.

Browse to the english.tin in Lab 1 folder

Change color of trace

ENSURE TOGGLE DISPLAY ONLY!

2. Select **Apply**.

**Figure 2a.  Typical *PowerCivil* Tutorial Slides.**

## Investigate DTM with Analysis Tools

3. Place the cursor anywhere on the EDP site, left click and the path of a raindrop will be depicted on the EDP site.

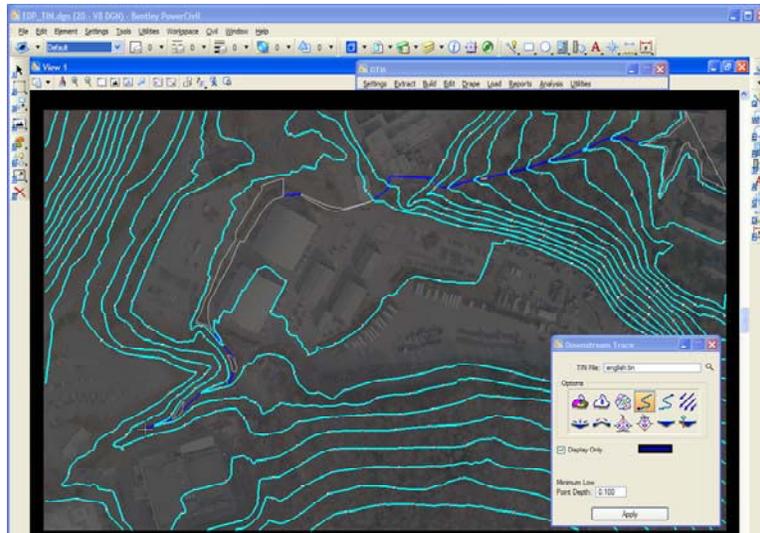4. Investigate the EDP site using this tool and close the tool when done.

**Figure 2b.  Typical *PowerCivil* Tutorial Slides.**

Four assessment tools were used to determine the effectiveness of the *PowerCivil* instruction in CE390 in the fall 2008 term: a muddiest point paper [17] conducted after Lesson 13, 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. Each assessment tool is discussed separately below.

## 1. Muddiest Point

The muddiest point paper[17] was given to the students during Lesson 14 and asked two questions pertaining to the *PowerCivil* instruction:

1) We have spent the majority of our lab time exploring the computer program *PowerCivil* 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 the out of class assignment?

The overall feedback on the tutorials was very positive. In response to the first question, only three of the 54 students surveyed stated that the tutorials were not effective. The most common feedback was that the students appreciated the ability to work at their own pace and not feel either rushed to keep up or bored because the pace was too slow. The three dissenting opinions all had the same issue which is best described in the following comments, "[The tutorials] allow me to get the needed product but I just follow the steps blindly without understanding how to do it. As soon as class is over I forget the process." The students' answers to the second question provide further insight into their actual working knowledge of the program. All 54 students were able to successfully complete the out of class conceptual site design assignment, but more than half stated they would not have been able to do so without going back and reviewing or reworking the tutorials from class. The following comment from a student that responded to the first question that the tutorials were great best illustrates this point. "As long as I had the tutorials I could do whatever task. However, without the tutorials I would be unable to do the assignment."

The instructors felt the students were still in the walk phase of the *PowerCivil* instruction and were showing through both their performance on the initial site plan and their own comments that they were where we expected them to be; that is, they could follow a tutorial in class to accomplish a given task and then take that same tutorial and apply it to a new but similar problem. One adjustment was made based on the student feedback - to make periodic comments throughout the lesson in order to reinforce the "bigger picture" that was presented at the beginning of the session. These global orientations never took more than a couple of minutes during which the instructor would stop all the students regardless of how far they were through the tutorial and discuss what they had accomplished thus far in the lesson.

## 2. EDP Final Submission

There were two embedded indicators [15, 16] within the final EDP submission to assess the effectiveness of the *PowerCivil* instruction. The preliminary grading plan and storm-water drainage plan, each were worth 25% of the final grade for a combined 50% of the EDP grade. The students were organized into groups of three students each for the EDP project providing a total of 24 groups with the following results:

Table 2. *PowerCivil* EDP Task Grades (%) (CE390, Fall 2008)

| Event | High | Low | Average | STD Deviation |
|---|---|---|---|---|
| Grading Plan | 100% | 58.3% | 85.8% | 12.7% |
| Storm-Water Design | 103% | 80.0% | 94.7% | 5.90% |

There is a noticeable difference between the grading plan and the storm-water drainage plan. This can be attributed to the method used to create each plan and the point distribution. The drainage tool in *PowerCivil* is very user friendly and it will not run if a mistake is made and points were allocated based on a working system as much as they were for a "correct" system. Conversely the grading plan is dependent on a good working model with all objects and elements correctly created and draped individually and points were allocated just as much for design decisions (building pad placement, elevation, earthwork balance, etc.) as for "correctness".

In general, every group produced a working model in *PowerCivil* and the results and grades met the instructors' expectations. One issue with using this data as an indicator was that it is a group grade and does not necessarily indicate the proficiency of all three group members. In general, each group had one student complete the grading plan and another student complete the storm water drainage plan, which left the third student out of the run phase of the developmental model. This will be addressed and investigated in depth with the next two assessment tools.

## 3. Course-End Survey

At the end of the last lesson the students 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 (*PowerCivil*) and computer aided-drafting (*PowerDraft*) software.

2) Explain the advantages of site designing with *PowerCivil*.

3) Explain the general process in *PowerCivil* to complete a site grading design.

4) Explain the general process in *PowerCivil* to complete a storm-water drainage design.

5) Use *PowerCivil* for a site design project in the senior design course (CE492).

6) Use *PowerCivil* for a site design project within five years of graduation.

The results for the course are provided below.  The confidence level is the average for all 54 students in each category.  A confidence index for each individual was determined by taking the sum of their individual confidence levels for each requirement and dividing by a maximum possible of 60.  The confidence index ranges from zero (no confidence) to one (fully confident).  The course confidence index is the average of the 54 individual confidence indices.

Table 3.  Student Confidence in *PowerCivil* (CE390, Fall 2008)

| Course Confidence Index | High | Low | Standard Deviation |
|---|---|---|---|
| 0.66 | 0.92 | 0.35 | 0.12 |

Table 4.  Course End-Questions and Average Student Confidence (CE390, Fall 2008)

| Confidence Level | Requirement |
|---|---|
| 5.38 | Explain the difference between modeling (*PowerCivil*) and computer-aided-drafting (*PowerDraft*) software. |
| 7.83 | Explain the advantages of site designing with *PowerCivil*. |
| 6.92 | Explain the general process in *PowerCivil* to complete a site grading design. |
| 6.67 | Explain the general process in *PowerCivil* to complete a stormwater drainage design. |
| 6.81 | Use *PowerCivil* for a site design project in the Firstie Design Course (CE492). |
| 5.71 | Use *PowerCivil* for a site design project within five years of graduation. |

The course confidence index has a wide range from 0.35 to 0.95 and a large standard deviation of 0.12.  The authors believe the wide spread is a direct result of the three person group organization as discussed in the *EDP Final Submission* section above.  Since each group had three members and there were only two main components of the final submission that required *PowerCivil*, the natural division of labor was to have two members work on *PowerCivil* while the third worked on the other requirements.  In fact, because the two *PowerCivil* requirements accounted for only half of the total points, some groups even put one person in charge of all the modeling while the other two focused on everything else to include the written requirements for the two *PowerCivil* sections.  It is important to note here that every student was brought through the walk phase of the developmental model, but only those who worked on their respective team designs really received the full benefit of the run phase.  In light of this division of work, the above sampling of 54 students was broken down and analyzed in groups of 18 based on their individual confidence indices.  The results of this analysis are provided below:

*Top Third:*

Table 5.  Top 1/3 Student Confidence in *PowerCivil* (CE390, Fall 2008)

| Top 1/3 Confidence Index | High | Low | Standard Deviation |
|---|---|---|---|
| 0.79 | 0.92 | 0.73 | 0.05 |

Table 6.  Average Student Confidence, Top 1/3 (CE390, Fall 2008)

| Confidence Level | Requirement |
|---|---|
| 6.81 | Explain the difference between modeling (*PowerCivil*) and computer-aided-drafting (*PowerDraft*) software. |
| 8.61 | Explain the advantages of site designing with *PowerCivil*. |
| 8.14 | Explain the general process in *PowerCivil* to complete a site grading design. |
| 8.11 | Explain the general process in *PowerCivil* to complete a stormwater drainage design. |
| 8.03 | Use *PowerCivil* for a site design project in the Firstie Design Course (CE492). |
| 7.42 | Use *PowerCivil* for a site design project within five years of graduation. |

*Middle Third:*

Table 7.  Middle 1/3 Student Confidence in *PowerCivil* (CE390, Fall 2008)

| Middle 1/3 Confidence Index | High | Low | Standard Deviation |
|---|---|---|---|
| 0.67 | 0.72 | 0.63 | 0.03 |

Table 8.  Average Student Confidence, Middle 1/3 (CE390, FALL 2008)

| Confidence Level | Requirement |
|---|---|
| 5.83 | Explain the difference between modeling (*PowerCivil*) and computer-aided-drafting (*PowerDraft*) software. |
| 7.71 | Explain the advantages of site designing with *PowerCivil*. |
| 7.33 | Explain the general process in *PowerCivil* to complete a site grading design. |
| 6.28 | Explain the general process in *PowerCivil* to complete a stormwater drainage design. |
| 6.89 | Use *PowerCivil* for a site design project in the Firstie Design Course (CE492). |
| 6.06 | Use *PowerCivil* for a site design project within five years of graduation. |

*Bottom Third:*

Table 9.  Bottom 1/3 Student Confidence in *PowerCivil* (CE390, Fall 2008)

| Bottom 1/3 Confidence Index | High | Low | Standard Deviation |
|---|---|---|---|
| 0.51 | 0.62 | 0.35 | 0.08 |

Table 10.  Average Student Confidence, Bottom 1/3 (CE390, Fall 2008)

| Confidence Level | Requirement |
|---|---|
| 3.50 | Explain the difference between modeling (*PowerCivil*) and computer-aided-drafting (*PowerDraft*) software. |
| 7.22 | Explain the advantages of site designing with *PowerCivil*. |
| 5.28 | Explain the general process in *PowerCivil* to complete a site grading design. |
| 5.61 | Explain the general process in *PowerCivil* to complete a stormwater drainage design. |
| 5.50 | Use *PowerCivil* for a site design project in the Firstie Design Course (CE492). |
| 3.67 | Use *PowerCivil* for a site design project within five years of graduation. |

The authors believe the break down shown in the tables above better represents the effectiveness of the *PowerCivil* instruction.  There is little difference between the three groups in their confidence to explain the advantages of using *PowerCivil* for site design which requires only a working knowledge of the program's capabilities.  However, there is a large drop from the top to the middle to the bottom third in their overall confidence level, and in their confidence to use the program to complete a site design project both now and in the future.

**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:

- (3 points) Explain the difference between modeling (*PowerCivil*) and computer aided-drafting (*PowerDraft*) software.

- (3 points) Explain the advantages of site designing with *PowerCivil*.

- (5 points) Explain the general process in *PowerCivil* to complete a site grading design.

- (5 points) Explain the general process in *PowerCivil* to complete a storm-water drainage 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 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 then 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 (2/3)*10 =6.67. The individual data was then averaged to obtain the proficiency level of each sample group for a particular question. The three sample groups (top, middle, and bottom third) were determined using the individual proficiency indices which are 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 *PowerCivil* (CE390, Fall 2008)

| Top 1/3 Proficiency Index | High | Low | Standard Deviation |
|---|---|---|---|
| 0.83 | 1.00 | 0.73 | 0.08 |

Table 12. Average Student Proficiency, Top 1/3 (CE390, Fall 2008)

| Proficiency Level | Requirement |
|---|---|
| 8.19 | Explain the difference between modeling (*PowerCivil*) and computer-aided-drafting (*PowerDraft*) software. |
| 7.78 | Explain the advantages of site designing with *PowerCivil*. |
| 8.00 | Explain the general process in *PowerCivil* to complete a site grading design. |
| 9.08 | Explain the general process in *PowerCivil* to complete a stormwater drainage design. |

*Middle Third:*

Table 13. Middle 1/3 Student Proficiency in *PowerCivil* (CE390, Fall 2008)

| Middle 1/3 Proficiency Index | High | Low | Standard Deviation |
|---|---|---|---|
| 0.65 | 0.73 | 0.60 | 0.04 |

Table 14.  Average Student Proficiency, Middle 1/3 (CE390, Fall 2008)

| Proficiency Level | Requirement |
|---|---|
| 5.42 | Explain the difference between modeling (*PowerCivil*) and computer-aided-drafting (*PowerDraft*) software. |
| 6.25 | Explain the advantages of site designing with *PowerCivil.* |
| 6.58 | Explain the general process in *PowerCivil* to complete a site grading design. |
| 7.58 | Explain the general process in *PowerCivil* to complete a stormwater drainage design. |

*Bottom Third:*

Table 15.  Bottom 1/3 Student Proficiency in *PowerCivil* (CE390, Fall 2008)

| Bottom 1/3 Proficiency Index | High | Low | Standard Deviation |
|---|---|---|---|
| 0.44 | 0.60 | 0.00 | 0.15 |

Table 16.  Average Student Proficiency, Bottom 1/3 (CE390, Fall 2008)

| Proficiency Level | Requirement |
|---|---|
| 2.92 | Explain the difference between modeling (*PowerCivil*) and computer-aided-drafting (*PowerDraft*) software. |
| 4.31 | Explain the advantages of site designing with *PowerCivil.* |
| 5.75 | Explain the general process in *PowerCivil* to complete a site grading design. |
| 4.75 | Explain the general process in *PowerCivil* to complete a stormwater drainage design. |

When comparing the graded requirement with the self assessment it appears that the top third of the class actually rated their own confidence slightly below their demonstrated understanding on the final exam and the middle third was close to even.  However, the bottom third performed well below their self assessed confidence level, especially in the areas of explaining the advantages of *PowerCivil* and the storm water design process.  This again reinforces the notion that the division of labor on *PowerCivil* tasks among the three group members on the EDP was not equal.

In general, the instructors were very pleased with the proficiency of the students in *PowerCivil* at the end of CE390 in the fall 2008 term.  Two thirds of the class rated themselves as 63% confident or greater in their abilities to use the program and that same two thirds demonstrated a 60% or better proficiency.  Additionally, the EDP final submissions averaged in the 85-95% range.  The instructors believe we reached or exceeded a reasonable level of understanding and application for the use of a professional civil engineering modeling software package in an undergraduate level course.

***PowerCivil* in CE492, CE Program Capstone Course, Spring 2009**

*PowerCivil* played an important role in the civil engineering program's capstone design course, CE492, in the spring 2009 term. The course was restructured significantly from previous years to include only three design groups. Each class section of 15 students was organized into a design team within a fictional engineering firm. The engineering firm was comprised of a vice president (senior faculty member) and a senior engineer (junior faculty member) in each specialty area (hydrology, geotechnical, structural, and site design). The project was to design a 4H Recreation Park for Orange County, NY. The primary tool for the site design team was again *PowerCivil* and their primary instructors were those who successfully taught the program in CE390 the previous term. Since this group of seniors was the same group of students that had a bad experience with *PowerCivil* the year prior in CE390 (fall 2007 term), the instructors thought it prudent to provide them additional formal instruction in the program. Each site design team was provided five one-hour lessons using the same tutorials from the CE390 site design course. This allowed the students to work on a real world problem to enhance the skills needed to complete their site designs. In addition, it required minimal extra work by the instructors because the tutorials were already used and vetted the previous semester.

The assessment tools used to determine the effectiveness of the *PowerCivil* instruction in CE492 included the site design products presented by each firm at the 10%, 35%, 65%, and 100% submissions. As of the date of this paper submission, the students are responding favorably to the CE390 tutorials and appear to be on-track to be effective in using *PowerCivil* for their capstone project.

**Conclusions**

The purpose of this paper was to discuss the challenges, assessments, and applied solutions associated with teaching the *PowerCivil* software package at the United States Military Academy. The authors fully appreciate that a few successes do not constitute victory. Additional work and effort is planned as follows:

- Further integrating the *PowerCivil* program into other CE courses as part of the bridge between CE390 and CE492. For example, use in the soils, foundation, structural analysis, and building design courses. There is currently a year between CE390 and CE492, and the software skills degrade quickly over time.
- Ensuring every student is actively engaged in using *PowerCivil* in the CE390 group projects. The previous CE390 EDPs were not sufficiently designed to ensure every student was running in the developmental model.
- Better tutorials that include additional background material to further enhance the student's appreciation of the power of the software. The tutorials currently provide the directions, but not enough information. The authors believed it was more important that the direction were correct prior to engaging in the development of background information.

- Faculty development needs continual emphasis in the department leadership. Faculty must be resourced with sufficient time to learn and maintain their knowledge of the software.

Modern engineering software has amazing capabilities and engineering students must develop a certain level of knowledge, appreciation, and skills in using the software. However, that which is valuable – is usually difficult to obtain. The authors believe that the techniques and assessment processes demonstrated in this paper will help advance the educational profession in the area of software instruction to better prepare our future engineers.

**Bibliography**

1. ASCE  (2008).  *Civil Engineering Body of Knowledge for the 21$^{st}$ Century – Preparing the Civil Engineer for the Future.* Second Edition.  Reston, Virginia:  American Society of Civil Engineers.
2. Accreditation Board for Engineering and Technology  (2005).  *PROPOSED Criteria for Accrediting Engineering Programs,* in CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS – *Effective for Evaluations During the 2006-2007 Accreditation Cycle*.
3. Grigg, N. S., Criswell, M. E., Fontane, D. G., Siller, T. J. (2005). "Information Technology in Civil Engineering Curriculum," *J. Prof. Issues Eng. Educ. Pract.*, 129(1), 26–31.
4. Clough, G. W. (2000). "Civil engineering in the next millennium." *New Millennium Colloquium*, Massachusetts Institute of Technology, Cambridge, Mass.
5. Bordogna, J. (1998). "Tomorrow's civil systems engineer—The master integrator," *J. Prof. Issues Eng. Educ. Pract.*, 124(2), 48–50.
6. Anderson, L.W. and L.A. Sosniak  (1994).  "Bloom's taxonomy:  A forty-year retrospective."  Ninety-third yearbook of the Nation Society for the Study of Education (NSSE), Part II.  University of Chicago Press.
7. Merriam-Webster's Online Dictionary  (2008).  Accessed Jan 1, 2008.  http://www.m-w.com/dictionary.
8. Bloom, B.S.  (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain*.  New York: David McKay Co Inc.
9. Krathwohl, D.R., B.S. Bloom, and B.M. Bertram  (1973). *Taxonomy of Educational Objectives, the Classification of Educational Goals. Handbook II: Affective Domain*. New York:  David McKay Co., Inc.
10. Simpson, E. (1972). *The classification of educational objectives in the psychomotor domain: The psychomotor domain*. Vol. 3. Washington, DC: Gryphon House.
11. Lynch, D.R., J.S. Russell, J.C. Evans, and K.G. Sutterer  ( 2008).  *Beyond the Cognitive: The Affective Domain, Values, and the Achievement of the Vision*.  ASCE Journal of Professional Issues in Engineering, Education, and Practice.  Reston, Virginia:  American Society of Civil Engineers, in press.
12. Hanus, J.P., Russell, J.S., Hamilton, S.  (2008).  *The Cognitive and Affective Domain in Assessing the Life-Long Learning Objective.*  In *ASEE National Conference and Exposition*.  Pittsburgh, PA.
13. United States Military Academy  (2008).  *Mission Statement*.  Accessed Jan 1, 2008.  http://www.usma.edu/mission.asp.
14. Department of Civil and Mechanical Engineering, USMA  (2008).  *Mission Statement*.  Accessed Jan 1, 2008.  http://www.dean.usma.edu/departments/cme/CME%20Home/mission.htm.
15. Meyer, F. (2008).  *Performance Assessment for Civil Engineering Curriculum.*  In *ASEE National Conference and Exposition.*  Pittsburgh, PA.
16. Meyer, F. (2007).  *A Direct Assessment Technique That Works.*  In *ASEE National Conference and Exposition.*  Honolulu, HI.
17. Angelo, T. A. and K.P. Cross (1993).  *Classroom Assessment Techniques*, 2nd Ed. Jossey-Bass Publishers, (1993).