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Influence of Integrating GPS and Civil 3D in Engineering Technology Courses

Dr. Maher M Murad, University of Pittsburgh, Johnstown

Dr. Maher Murad is a faculty member in the Civil Engineering Technology department at the University of Pittsburgh at Johnstown. Dr. Murad served as a visiting professor at Bucknell University. He also has overseas teaching and professional experience. He worked as a technical manager at Modern Contracting and as a highway project manager at Acer Freeman Fox International. He is a licensed professional engineer (P.E.) in the state of Ohio. Dr. Murad received a Masters degree in Civil Engineering and a Ph.D. in Engineering Science from the University of Toledo.

Mr. Brian L Houston P.E., University of Pittsburgh, Johnstown

BRIAN L. HOUSTON is an Associate Professor of Civil Engineering Technology at the University of Pittsburgh at Johnstown. Prior to academia, he worked as a Senior Design Engineer in the petrochemical industry and is licensed in several states. He continues to provide structural engineering consulting services for industrial contractors and fabricators. He received a B.A. from Northwestern University in 1986, and a B.S./M.S. in Civil Engineering from Oklahoma State University in 1997/99.

Influence of Integrating Geographic Positioning System (GPS) and Civil 3D in Engineering Technology Courses

Abstract

In order to remain current in surveying practices, the Civil Engineering Technology (CET) department at the University of Pittsburgh at Johnstown (UPJ) purchased advanced GPS equipment for use in conjunction with the available traditional surveying equipment. Four CET courses (Elementary Surveying, Civil Computation and Design, Highway Surveying and Design, and Senior Project) require the utilization of surveying data. Network-licensed, Autocad programs [Autocad and Autocad Civil 3D] are the standard software products used in CET instruction, and are the typically used by CET students in completing tasks in the aforementioned courses. Integrating GPS equipment and Civil 3D has improved courses and is expected to better prepare our graduates for careers in the civil engineering industry. The CET department emphasizes incorporating current technologies and computer applications as part of the CET continuous improvement plan, heavily emphasized by the Accreditation Board for Engineering and Technology (ABET).

This paper describes the pedagogical aspects of developing, teaching, and coordinating four CET courses to maximize the use of the GPS equipment and Civil 3D software as well as discussing the positive impact this has on student learning. Related course components are presented and discussed. Feedback from students is also discussed. The experience gained may be useful to those considering ways to develop and teach enhanced courses that meet both ABET criteria and industry demands.

Introduction

The University of Pittsburgh at Johnstown offers a 4-year Bachelor of Science degree in Civil Engineering Technology. Accreditation Board for Engineering and Technology outlines Civil Engineering Technology Program Criteria for accreditation.(1) One of the requirements of the ABET general criteria is that an Engineering Technology (ET) program must demonstrate that graduates have an appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines. Another criterion requires graduates to have an ability to identify, analyze and solve technical problems. In addition, CET program specific requirements include that graduates be capable of utilizing principles, hardware, and software that are appropriate to produce drawings, reports, quantity estimates, and other documents related to civil engineering. Other requirements call for graduates to be capable of applying basic technical concepts to the solutions of civil problems as well as performing standard analysis and design in at least three areas.

The CET program as a whole is expected to meet the above criteria with contribution from the different courses offered. Integrating GPS and the Civil 3D software into CET courses is believed to be a step to help achieve the above mentioned ABET accreditation criteria as further discussed in the following sections.

Background on the purchase of the GPS Equipment

The CET department purchased GPS equipment utilizing an academic program provided by the manufacturer which enable procurement of equipment at 10% of the retail cost. Initially this equipment was envisioned to be used primarily in an elementary surveying course. But it quickly became apparent that due to the short learning curve and ease of use, this technology could be greatly advantageous to upper level students taking the highway surveying and design course, along with those working on their senior design projects. The GPS equipment enables students get the coordinates of any point easier and much quicker than traditional surveying equipment. Historical methods would require between 16 and 24 hours of surveying to obtain sufficient data for a Senior Project, typically around 200 data points. With the newer GPS equipment, a student surveying crew can collect 500 points in approximately four hours. This efficiency provides more data, better land surface development, and shifts work time into the analysis and interpretation of data, as opposed to collection, which is ultimately the goal of Senior Project.

AutoCAD® Civil 3D® software is a civil design and documentation solution that supports Building Information Modeling (BIM) workflow. It is used to better understand project performance, maintain more consistent data and processes, and respond faster to change.(2) The software is available along with a number of other computer programs on the UPJ computer network. The software covers topics that include roadway design, hydrology, site grading, and surveying. In addition it allows students to compute cut/fill volumes and perform mass balance operations.

Application Courses
Surveying

In the surveying course, students are trained to use both traditional and modern surveying equipment including tapes, automatic levels, total stations, and GPS equipment. The use of such equipment allows students to complete basic surveying tasks such as differential level loops, closed traverse studies, and hand-drawn topographic maps.

Traditional methods and techniques [including steel taping] are included both for historical perspective, as well as the unique opportunity they provide in demonstrating how basic engineering concepts [such as thermal expansion] are used in many other areas within their discipline. The gradual transition from old to new technology helps the student learn simple techniques that are economical, fairly simple, and require low tech equipment, as well as state of the art methods and equipment. Their actual experience is unpredictable, because often the type of equipment they encounter in the field is a function of the size and financial position of the firm for which the work.

Civil Computations and Design (CET0021)

This three credit course is required of all CET sophomore students. Students must have taken the surveying course as a prerequisite. The course is a continuation of surveying principles and calculations. It utilizes data collected during the surveying course. The course introduces students to site development and mapping AutoCAD Civil 3D. This is a laboratory oriented course. Students carry out assignments on a variety of topics including traverse surveys and topographic mapping. The use of Civil 3D software is presented to students through an active session using real examples. Each student is required to demonstrate an ability to use the program by doing the assignment in a step-by-step approach along with the instructor.

Part of the data is collected manually using total stations and the rest is collected using GPS equipment. The electronic output file from GPS can be easily read by Civil 3D which has been utilized to help students complete tasks including traverse computations, layout, and electronic topographic maps. Students bring the data they collected in surveying manually and using GPS. The data is related to a closed traverse, topographic, and planimetric features. Students also bring the traverse report they prepared manually. Data is entered in Civil 3D and a traverse layout and computations including linear closure and coordinate checks are generated. Students get the opportunity to compare their manual report from surveying with that produced using Civil 3D. Students develop an AutoCAD based topographic map that includes a layout of the closed traverse along with planimetric features such as buildings, sidewalks, lamp posts, fire hydrants, manholes, and trees. The map should have a legend, notes, and a title block. Finally, students design a parking lot utilizing Civil 3D including the layout and earthwork computations.

Highway Surveying and Design (CET1121)

This is an elective upper-level CET course. Only senior students take the course. It is preceded by the transportation required course at the junior level and two other sophomore level courses (elementary surveying and civil computations). The course has been designed to meet ABET criteria for design courses. The course is design and problem solving in nature. It develops students' ability to use mathematical formulas, specifications and guidelines by design agencies, assumptions, and common sense to recommend solutions for a given highway problem.

The Laboratory in this course involves a semester long project to design a road including horizontal and vertical alignments, cross sections, and earthwork computations. Students carry out a route survey using traditional surveying equipment (mainly total stations). The surveying portion of the class would typically take two weeks to finish because of the rugged, wooded terrain and poor visibility within the survey area. Students used to limit the survey to measuring the distances from each point of intersection (PI) to the next one along with the deflection angles. Students then complete a traverse analysis and find the coordinates of the project PI points.

After a review training session on how to use and take care of the GPS equipment, students are allowed to use it instead of the total station. Students are able to finish the survey in a short period of time (less than three hours). In the past, students had to be provided with topographic maps of the area because it is very difficult and time consuming to conduct a topographic survey in the project area. But now students can carry out a topographic survey in a short period of time. The output of the survey is a text file listing the points and their coordinates as well as their descriptions. This kind of electronic output works best if the design is to be done using a design software that can read this data file such as Civil 3D. The survey handouts are re-written to include the option of using the GPS equipment in the route survey. The new design handouts reflect the use of Civil 3D software for the design of geometric components of the project, encouraging students to use this procedure replacing the lengthy manual work except for verification and sample calculation.

The design software is introduced to students to aid in the analysis and design of a highway facility. Initially, the software is introduced as a demonstration class to illustrate the designing ability of the software, especially performing design calculations and producing project drawings. The plan to integrate Civil 3D software into the course is presented to students on the first day of classes. The idea is discussed along with the course syllabus. The intention of using the software as a learning tool and as a way to aid in both analysis and design is also discussed.

Cooperative learning is used as the instruction style in the laboratory. Cooperative learning is defined as instruction that involves working in teams to accomplish an assigned task and produce a final product, under conditions that include the elements: *Positive Interdependence, Individual Accountability, Face-to-Face Interaction, Appropriate Use of Teamwork Skills, and Regular Self-assessment of Team Functioning* .[(3)] An extensive body of educational research confirmed the effectiveness of cooperative learning in higher education. [(4)] The term “Team” is used here and not “Group” because in teamwork, activities span for a long time (weeks, whole semester) while activities span short time frame for group work. Also, teams are formed carefully while groups are formed spontaneously. [(5)]

Students work in teams of three or four and are carefully formed by the instructor. Academic research indicates that instructor formed teams perform better than totally self-selected teams. [(6)] At the beginning of the semester, students are asked to fill out a student data sheet in which they provide information about their technical background and experiences inside and outside of school as well as their interests. The student data sheet provides feedback on each student’s prior learning to help determine the “starting” point of instruction. [(7)] The student data sheet also includes information that will help the instructor in team formation. One provision of team formation is for each student to identify a student with whom he/she would like to work and one student with whom he/she would prefer not to be teamed. [(8)] Students are told that their choices will be taken into consideration but are not guaranteed because of feasibility problems such as the case when many students name one student whom they wish to work with.

The Civil 3D design software is integrated into the course through a semester long project assigned to the students at the beginning of the semester. The project is broken into tasks that can be completed in one or two weeks. The requirements of each design assignment is outlined and given to students as a handout. The students first carry out the design tasks using Civil 3D software and then deign specific selected elements manually to fully understand the design process verify the software results. Students then use the advanced features of the software to carry out sensitivity analysis and produce different design alternatives in a relatively short time.

The capacity of the laboratory is limited to 20 students to allow for full interaction between students and instructors to ensure that students follow the instructions correctly. The use of the software is presented to students through an active session using a real design example. The presentation follows a carefully planned outline, with built-in questions and side notes to stimulate class discussions as well as to motivate students’ interests. Each student is required to get access to the software and to work out a design example in a step-by-step approach along with the instructor. Students also take notes on the discussions of advanced features that may not be included in the example but could be part of their highway design project. The students get a tutorial hand out to help them perform the different tasks. They are also required to complete a reading assignment from the lab textbook, which provides a basic understanding of the tools found in Civil 3D software. [9]

The design requirements are mixed between being general (open-ended) and specific in order to allow members of each team to search for feasible solutions that meet the American Association of State Highways and Transportation Officials (AASHTO) or the Pennsylvania Department of Transportation (PennDOT) design guidelines. As a result, different teams may end up with different design solutions. Grading student performance and teamwork is done such that individual accountability is considered in the grading. With each submission, students are asked to fill a sheet to report on the rating of each team member with respect to the degree to which each member has fulfilled his/her responsibilities in completing the lab assignment. [7] The Auto-rating System is used to assign a final grade to each team member. [10]

Senior Design Project (CET1199)

The three-credit course is required of all senior CET students. In this course, every team surveys a project site to develop a topographic map. Historically this survey would take three eight-hour sessions to complete, often requiring three or four days of activity. By utilizing the GPS equipment, students can collect three to four times the data in approximately four hours, reducing the survey portion to a single activity, easily scheduled in a morning or afternoon session. Students embrace using the GPS equipment as they manage to finish their surveys in a remarkably short period of time, and the responsibility of using expensive equipment in an independent activity helps transition them mentally into practical engineers.

Students usually collect data and perform the design tasks during their last semester at UPJ. In the previous semester, student teams must prepare project proposals that are used as basis for their design activities. Teams work on a variety of design ideas with structural, environmental, and transportation themes. In almost all projects, students use GPS to collect data to create a topographic map in Civil 3D as part of the project site development. Students utilize Civil 3D extensively if the project is in the area of transportation such as highway and pavement design, bridge replacement, intersection design, and residential land development.

Feedback From Students

A questionnaire was administered during the CET seminar to obtain feedback from students on the idea of integrating the GPS equipment and Civil 3D software in CET courses. The questionnaire consists of eighteen questions. Seventy five students participated in the survey. The first question asked about the current academic standing of the student filling the survey. About equal numbers of sophomores, juniors, and seniors participated in the survey. The second question asked the students to recall the courses in which they utilized either the GPS or Civil 3D software. Figure 1 shows the distribution revealing that almost all students who participated in the survey took surveying and used the GPS equipment. But only the juniors and seniors took both the surveying and civil computations courses and utilized the GPS and Civil 3D software.

Only the seniors could have taken the highway design elective and the required senior design project.

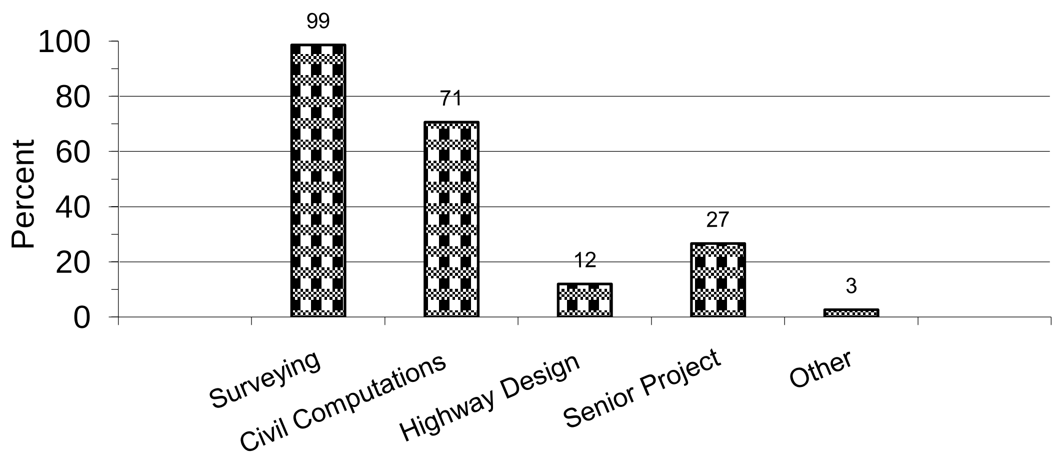

Figure 1: Courses in which you have utilized either GPS or Civil 3D

In the remaining sixteen questions, the answer format is multiple-choice such that the range of responses is from "1" meaning "Strongly Disagree" to "5" meaning " Strongly Agree ".

Table 1 gives the students' responses with respect to the usefulness of utilizing the GPS equipment. Five questions targeted this category with all students responding to the questions. The percent of maximum score and the weighted average response were used to quantify the response by students to these questions. The maximum score is the number when all students select “Strongly Agree" which has a value of five as their response in favor of the idea (i.e. maximum score = 150 for a class of 30 students). The percent of maximum score is the ratio of total question score divided by the maximum score expressed as a percentage.

Table 1: Students' responses to questions on utilizing the GPS equipment

No.	Question	Response	
		% Of Maximum Score (Max=100)	**Average (5 for strongly agree)**
1	Using the GPS equipment was relatively easy and needed only one training session	83	4.1
2	Using the GPS equipment for a survey takes much less time compared to a total station	98	4.9
3	The GPS allows for collecting a large amount of data in a relatively short period of time	96	4.8
4	The weather conditions can affect the data collection efficiency using GPS	74	3.7
5	GPS data file can be easily downloaded to a flash drive and loaded to Civil 3D	81	4.1

The following observations can be made from Table 1:

- The majority of students agree that using the GPS equipment was relatively easy and needed only one training session. They strongly agree that using the GPS equipment for a survey takes much less time compared to a total station and allows for collecting a large amount of data in a relatively short period of time. This is based on their experience as they tried both methods.
- Some students do not realize that adverse weather conditions may affect the data collection efficiency using GPS. Senior students are likely to understand this challenge from their experience using the GPS extensively and in places where the satellite availability may be limited.
- Students in general agree that GPS data file can be easily downloaded to a flash drive and loaded to Civil 3D. They may have to carry out a couple of steps to clean up the file to make it matching one of the formats that Civil 3D uses to read data.

Table 2 presents the students' responses with respect to the usefulness of utilizing the Civil 3D software in the civil computations course. Six questions targeted this category with students who took at least the surveying and civil computations courses could respond to the questions. An average of fifty four students responded to the questions.

Table 2: Students' responses to questions on integrating GPS and Civil 3D software

No.	**Question**	**Response**	
		% Of Maximum Score (Max=100)	**Average (5 for strongly agree)**
6	Civil 3D software enabled me to verify and complete traverse computations	84	4.2
7	Civil 3D software enabled me to prepare an AutoCAD-based topographic map	86	4.3
8	My background in AutoCAD made it relatively easy for me to use Civil 3D software	78	3.9
9	Learning to design using Civil 3D software is likely to be helpful when using other software	83	4.1
10	The experience from utilizing Civil 3D software is likely to give me an employment advantage	88	4.4
11	I believe integrating the GPS and Civil 3D in courses is a useful practice that should be continued	92	4.6

The following observations can be made from Table 2:

- Students who took surveying followed by the civil computations course agreed that Civil 3D software enabled them to verify and complete traverse computations which they completed manually in surveying. The software also made possible for them to prepare an AutoCAD-based topographic map including features such as buildings and walkways.
- Students indicated their background in AutoCAD made it relatively easy to use the Civil 3D software. Students take AutoCAD in their freshman year. The experience helps them develop proficiency with Civil 3D software, which is AutoCAD based. The relatively low score is an indication that the software has many new commands. Students will have to practice no matter how good they are in AutoCAD.
- Many students from their summer internship or part-time employment realized that the design process using Civil 3D software is not very different from other software. Therefore, the experience they gained from using this software is likely to be helpful when using other design software.
- The majority of students feel that learning the design process using the Civil 3D software is likely to give them an employment advantage. Private consultants and government agencies all use some kind of software in the analysis and design of civil engineering facilities and are likely to prefer graduating engineers with some experience in using design software.
- The vast majority of students believe that integrating the GPS equipment and Civil 3D software in CET courses is a useful practice that should be continued.

Table 3 presents the students' responses with respect to the usefulness of utilizing the Civil 3D software in the design of civil engineering projects. Five questions targeted this category. Only students who took highway surveying and design and/or senior design courses could respond to the questions. An average of nineteen students responded to the questions.

Table 3: Students' responses to questions on integrating GPS and Civil 3D software in design

No.	Question	Response	
		% Of Maximum Score (Max=100)	Average (5 for strongly agree)
12	Civil 3D software helped me understand the design process better	85	4.3
13	Civil 3D software allows for producing different design alternatives in a relatively short time	84	4.2
14	Civil 3D software helped me design a road according to AASHTO design standards	84	4.2
15	Civil 3D software produces professional drawings with settings controlled by the designer	87	4.4
16	When using Civil 3D software, I understand that I am the designer and not the software	85	4.3

The following observations can be made from Table 3:

- Senior students and those who took the highway design course appear to have a good feel of the abilities of the software in analysis and design including the software's ability to produce different design alternatives in a relatively short time, the software's ability to design according to AASHTO design criteria and to produce professional drawings.
- Students who utilized Civil 3D in design agree that they are the designers and that the software is only a tool to aid in the design process. Students also understand that the feasibility and quality of their designs reflect the ability and experience of the designer and not necessarily the software. A neat computer output does not necessarily mean a good design. In other words, the designer takes the credit or the blame for the quality of design.

While additional comments were allowed, few were received. Of those documented, several seemed to indicate both GPS and Civil 3D were productive and useful tools.

- "*Several jobs I have applied for called me because of my Civil 3D experience*"
- "*GPS survey is a very effective way to collect large amounts of data relatively easily!*"
- "*Civil 3D does produce professional looking drawings with little effort"*

Surely any conclusions from these comments is anecdotal at best, and review and interpretation of the aforementioned data is a much better predictor of the use and efficacy of these methods.

Conclusions

A CET program as a whole is expected to meet ABET criteria with contribution from the different courses offered. Integrating GPS and Civil 3D software into CET courses is shown to be a step that can help achieve part of the accreditation criteria. Students taking four CET courses have benefited from utilizing the GPS equipment. Students can collect large data in a short period of time, reducing the survey to a single activity, easily scheduled in a morning or afternoon session. Students embraced using the GPS equipment and the responsibility of using expensive equipment in an independent activity may help transition them mentally into practical engineers. Adverse weather conditions may affect the data collection efficiency using GPS if performed in places where the satellite availability may be limited. Students in general agree that GPS data file can be easily loaded to a software such as Civil 3D.

Students can utilize the Civil 3D software to verify and complete traverse computations. They can also prepare an AutoCAD-based topographic map that may include features such as buildings and walkways. The experience students gain from using this software is likely to be helpful when using other design software. The software can assist students in analysis and design including the ability to produce different design alternatives in a relatively short time, design a road according to AASHTO, and produce professional drawings. But students must understand that the feasibility and quality of their designs reflect the ability and experience of the designer and not necessarily the software. In addition, learning the design process using the Civil 3D software appears to give students an employment advantage. Most CET students expressed appreciation for integrating the GPS equipment and Civil 3D software in CET courses as useful practices that should be continued. It is recommended that CET courses be designed with objectives including successful teamwork and hands on experience utilizing advanced equipment and design software such as GPS and Civil 3D in order to meet both ABET criteria and industry demands.

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