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Engineering Education and a Field Journal at Construction Sites*

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Civil engineering graduates report that exposure to actual construction sites during their undergraduate training may be beneficial to their career development. This research describes the incorporation of a field journal assignment at construction sites into a land development engineering course. The authors sought to determine if student observation of active construction would result in self-reported increased proficiency in two areas: field journal skills and construction engineering skills. Results suggest that this assignment does facilitate students' proficiency in these two skills sets and can increase students' understanding of the complexity involved in active construction sites.

Keywords: on-site learning; field journals; construction engineering; civil engineering

INTRODUCTION

LAND DEVELOPMENT brings together many disciplines in civil and environmental engineering, including construction management and engineering. According to feedback from many civil engineering graduates, their first contact with actual construction in the field is sometimes post graduation and they feel disoriented and confused [1]. Therefore, land development engineering students would benefit from closer contact with actual construction as part of their academic program. This can be accomplished by bringing construction site aspects into the classroom or by bringing the classroom to the construction site [1].

The Civil and Environmental Engineering Department at the University of South Carolina recently launched an introductory course in land development for engineers. This department does not have a focus area in construction engineering or management. To introduce students to construction, a field journal assignment to observe construction at a nearby construction site was incorporated into the syllabus for the first offering of this course in the Fall of 2003 [2]. This field journal technique also facilitated students' development of skills in maintaining a field journal, an important communication technique used in land development and construction and many other fields, and allowed the students to improve their spatial visualization of engineering designs. Communication skills are recognized by the Accreditation Board for Engineering and Technology (ABET) and others as an important outcome in engineering higher education, and spatial visualization is considered to be an important component for successful engineering [3–6]. The results from a student self-evaluation survey of the initial study were very positive, indicating that students believed they had improved their field journal skills and their construction activity knowledge in all categories surveyed [2]. These survey categories included some emerging issues, such as sustainable development, human factors, health and safety, addressed in a New Paradigm for Engineering Education in engineering journals [7].

The field journal assignment was again incorporated into the course curriculum in the following year with some minor modifications based on student suggestions, and the survey was again administered to validate the first year's results. In both cases, the first author, who was also the class instructor for both course offerings, identified six survey items for evaluating each of the two overall categories of field journal and construction engineering skills. These items had been chosen based both on the construction experience of the instructor and applicable ABET criteria. In both cases, the survey was administered on a pre/post basis. The surveys also included some additional questions and comment sections, which were expanded in the second offering.

This paper presents and compares data associated with a field journal assignment collected from the initial 2003 and subsequent 2004 offering of the above described introductory course in land development. The purpose for collecting and comparing these data was to determine if students' participation in regular on-site observations of an

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active construction site would result in the self-reporting of increased proficiency in two broad skill areas deemed important for success in many areas of civil engineering: field journal skills and construction engineer skills.

METHODS

Do students who regularly observe an active construction site report a gain in field journal skills and construction engineering skills? To build a foundation for the response to this question, this section provides full details about students' observation and field journal requirements, the observed construction sites, and the self-report data sources.

Journal assignment

The field journal assignments were given in the first class sessions in both the Fall of 2003 and the Fall of 2004 Land Development for Engineers class in the Civil and Environmental Engineering Department of the University of South Carolina (ECIV 570). The students were asked to visit a nearby construction site several times over a few months. Each time they were required to log their observations over a minimum number of pages in a notebook. The topics of their observations were not mandated so that the individual students could focus on engineering, environmental or construction activities of interest to them or related to their individual fields of study. The method of portraying the information was also optional so that the students could use text, drawings, photos or a combination as their preferred method of logging their observations. The students were not required to read any material specifically relating to construction engineering or management prior to or during the journal assignment. In both cases the assignment represented 10% of their overall grade in the class. In each year the student populations consisted almost entirely of senior level undergraduate civil and environmental engineering students with a small percentage of juniors and graduate students.

Fall 2003 offering

In the Fall of 2003 the students were asked to visit the neighboring construction of a university residence facility on nine separate occasions spaced nearly equally over a period of eleven weeks. The project was close by and of a fairly large scale ($\pm$29 million dollar value) so that there would be many items to choose from for observation. Over this period the construction went from a rough graded site to completion of much of the structural and exterior work. This site was also unique in that it represented the first attempt of the University of South Carolina to obtain the US Green Building Council (USGBC) LEED® (Leadership in Energy and Environmental Design) certification of a facility on its main campus in Columbia, South Carolina [8,9].

The students were expected to fill at least three pages in a small notebook provided for the assignment for each visit, which was estimated to take about 30 minutes of their time at the location, not including travel time. For safety and construction efficiency reasons, the students were not allowed on the site, but were required to make their observations from the perimeter. The University also provided the class with a set of drawings on the project that the students had access to in case they were interested in comparing the site observations to the plans. The journals were read by a third party so that they could be graded for being completed, not content, and represented 10% of their semester grade for the course. The intent was to be an exercise in observation, not an exercise in construction engineering review or inspection since construction engineering review and observation are considered to be under the authority of the professionals hired for the project, not the engineering education faculty or students. The topic(s) observed were chosen by the students and were varied, although it was recommended that they try to follow one or more of these topics on several occasions to better understand construction sequencing. Students observed workers, construction equipment, the constructed facility, 'green' topics or other aspects such as safety.

Fall 2004 offering

In the Fall of 2004 the students were asked to visit the nearby construction of a new university facility for the School of Public Health, including laboratory, office, classroom, and support space. They were asked to visit the construction on five separate occasions spaced nearly equally over a period of nine weeks. Over this period the construction went from a rough graded site to the initiation of building construction. This site also represents an effort of the University of South Carolina to obtain USGBC LEED® (Leadership in Energy and Environmental Design) certification of a facility on its main campus in Columbia, South Carolina. They were expected to fill at least four pages of the small notebook provided for the journal which was estimated to take about 45 minutes of their time, not including travel time. This second journal assignment differed from the first in that there were fewer, but longer visits to the site over a similar time period. This was at the suggestion of some of the students who were given the assignment the first time to have visits a little less often, but more comprehensive as sometimes site conditions did not change as quickly. All the other requirements on the second field journal exercise were equivalent to the first assignment.

Survey

In both 2003 and 2004 an initial survey was given to the students near the beginning of the assignment period and a final survey was given

after all the entries were completed. The initial and final surveys were identical in the rating questions, asking the students to describe their own opinion of their competency in twelve different skills. The intention was to see if they rated themselves differently for these twelve skills from the commencement to the end of the assignment. Anonymity is important when administering these types of surveys so that the students do not feel pressured to improve their rating to impress the instructor. Consequently, both the initial and the final surveys were paired to the same individual by the use of the last four digits of the student's social security number, while still maintaining the student's anonymity.

The initial survey in the 2003 trial contained only these twelve rating questions, with two additional fill-in questions included for the 2004 trial asking about the students' past experiences with field journals and their suggestions about what an experienced civil engineering project manager might have for taking field notes. The final survey in both trials contained these twelve rating questions and two additional fill-in questions at the end. These questions asked the students if they thought they may have originally estimated their skills incorrectly and if they had any further suggestions or comments on the journal assignment.

As mentioned in the previous analysis on the first trial given in 2003, the twelve different skills rated were divided into two categories, one focusing on field journal skills and the other relating to construction engineering skills. For the first ratings of competency in field journal techniques, the items concentrated on communication and observational skills under field conditions, whereas the construction engineering skills that were tracked emphasized construction engineering knowledge and proficiency. Both sets of skills were chosen by the instructor based on her experience and knowledge in construction and recording of field information. The categories are:

Category I: Field journal skills
1. Labeling journal for who, what, when, where
2. Taking notes under variable field conditions
3. Field sketching
4. Observing details
5. Recording details
6. Reporting information objectively and with integrity

Category II: Construction engineering skills
1. Sequence the steps needed to perform a construction activity
2. Estimate the human workforce needed for a construction activity
3. Describe the tools/equipment needed to perform a construction activity
4. Recognize health, safety and environmental issues related to a construction activity
5. Estimate the time needed to perform a construction activity
6. Visualize how the item under construction might appear on a plan

The students were asked to rank their competency on a Likert scale, a commonly used attitude scale in educational research [10]. Scale response options ranged from 1 to 5 with 1 being 'not yet competent' and 5 meaning 'very competent'. This type of self-evaluated pre/post rating survey has been used previously by engineering faculty at the University of South Carolina in evaluating other activities [11]. Copies of the 2004 initial and final survey forms are in Appendix.

Interview

To better understand survey results, data collection was expanded in 2004 to include interview data. Upon completing their Fall 2004 journals, students were invited to participate in a post journal assignment interview conducted by the second author or by a graduate assistant. In exchange for their participation, each student received one 'extra credit point' (1 percentage point) to be applied to their overall ECIV 570 grade. Each interview lasted no more than 20 minutes, and all interviews were conducted during the last lab session of ECIV 570. Interview questions were designed to further assess the construction engineering skills that students developed through their completion of the journal assignment. Items included in the interview protocol captured students thoughts about their developing skills in the first five skills comprising the construction engineering skill set (e.g., sequencing steps, estimating the workforce, etc.). All responses were recorded and transcribed, and emergent themes from responses to each question were identified.

RESULTS

Do students who regularly observe an active construction site report a gain in field journal skills and construction engineering skills? This section details results of survey and interview data gathered in an attempt to respond to this question.

Survey results

Eighteen students completed both the initial and final surveys in 2003 and 26 students completed both in 2004. The average ratings for each of the two categories surveyed in both years are tabulated in Table 1. These values have been rounded up to only one decimal point in the table, but three significant digits were used in follow-up calculations. Initially, in both trials, the students ranked their field journal skills (average 3.5 and 3.4 respectively out of 5) as significantly higher than their construction engineering skills (average 2.8

Table 1. Average survey results

Data set	2003			2004		
Survey	Initial avg. rating	Final avg. rating	Increase (%)	Initial avg. rating	Final avg. rating	Increase (%)
Category I: Field journal skills: overall	3.5	4.0	16	3.4	4.3	27
Category II: Construction engineering skills: overall	2.8	3.6	30	2.6	3.7	43

and 2.6 respectively out of 5). After the assignment was complete, they felt that their average field journal skills had increased from between 16% and 27%, and that their construction engineering skills had increased even more in both trials. Of note are the almost identical initial and final average ratings for both of the categories in both trials.

A closer look at data associated with the individual skills presented in Table 2 comprising the field journal skills and the construction engineering skills reveals that in each case, students report that the journal assignment had increased their competency. These values have been rounded up to only one decimal point in the table, but three significant digits were used in follow-up calculations.

In regard to the six measures of field journal skills, the 2004 class self-reported outperforming the 2003 class across all measures, although results were fairly consistent between the two groups in areas associated with observing details, recording details, and reporting information objectively and with integrity In the areas of notable difference (labeling the journal, taking notes under variable field conditions, and field sketching), the 2003 class routinely rated themselves higher initially than did the 2004 class, but both classes ended with very similar final average ratings.

In regard to the six measures of construction engineering skills, the 2004 class again indicated that they had outperformed the 2003 class across all measures, although results were fairly consistent between the two groups in areas associated with estimating the human workforce needed, describing the tools and equipment needed, and recognizing health, safety and environmental issues related to construction activity. In the areas of notable difference (sequence the steps needed, estimate the time needed, and visualize the item on a plan), the 2003 class routinely rated themselves higher initially than did the 2004 class, but both classes ended with very similar final average ratings.

The final surveys in both years also had space for writing additional comments and recommendations. In general, these comments were very positive and recommended using this technique in future land development and engineering classes. For example, comments included, 'It forces students to see the complexity of construction' and 'This [assignment] is a good idea. Engineers need to see the 'big picture' and not just crunch numbers!'

As previously mentioned, the 2003 trial did produce some comments about having fewer, longer assignments spaced farther apart. This was made a part of the second trial and there were no other significant comments regarding the frequency and spacing of the assignment times after the second trial was completed. In 2004, student comments suggested scheduling opportunities to meet with the construction manager; subsequently, the project manager for the site to be observed in Fall 2005 is scheduled to attend the first class session of ECIV 570 and help orient the students to the site.

Table 2. Individual skill surgey results

Data set	2003			2004		
Data Skill	Initial avg. rating	Final avg. rating	Increase (%)	Initial avg. rating	Final avg. rating	Increase (%)
I-1: Labeling journal	3.7	4.1	11	3.4	4.4	30
I-2: Taking notes under variable field conditions:	3.4	3.9	15	3.2	4.2	33
I-3: Field sketching	3.2	3.9	20	3.2	4.2	32
I-4: Observing details	3.4	4.1	21	3.5	4.4	25
I-5: Recording details	3.3	3.9	20	3.4	4.3	25
I-6: Reporting information objectively and with integrity	3.7	4.0	10	3.5	4.1	16
II-1: Sequence the steps needed to perform a construction activity	2.8	3.6	27	2.6	3.8	44
II-2: Estimate the human workforce needed for a construction activity	2.3	3.4	48	2.2	3.4	54
II-3: Describe the tools/equipment needed to perform a construction activity	2.8	3.9	42	2.9	4.0	39
II-4: Recognize health, safety & environmental issues related to a const. activity	2.9	3.9	37	2.8	4.0	41
II-5: Estimate the time needed to perform a construction activity	2.6	3.2	22	2.3	3.3	46
II-6: Visualize how the item under construction might appear on a plan	3.3	3.7	12	2.8	3.7	33

Interview results

Twenty-one students agreed to participate in the 2004 post journal assignment interview. Interview responses provided insight into how students felt about their perceived competence in each of the skills comprising the construction engineering skill set, category II of the individual skill survey.

Students began their interview by describing what they learned about planning, scheduling and executing construction during their observations. Overwhelmingly, students reported being surprised by the complexity of timing of on-site activity, and as a result, becoming more aware of the sequence of steps needed to perform a construction activity. Representative comments included, 'It was just a lot more involved than I realized, and there are a lot of steps you have to take . . .'; 'If you don't do things in the right order, you are going to have a lot of mistakes'; 'I observed the dependence of the stage of construction on what happens next'; 'There are several things that have to be done before other things can be done.' One student realized that not only were site activities carefully sequenced, but that this sequence was both linear and parallel, 'There were simultaneously half a dozen to a dozen different jobs on the site and different stages. In one corner . . . the steel was going up . . . in another corner . . . foundations were being poured. And in another corner, they were staking out and surveying.'

Most students indicated that they were surprised at the number of people simultaneously working on the site. They observed that the workers communicated in various ways (e.g., 'a lot of hand signals'; 'everyone had their little radios'; 'You'd better speak Spanish!') and that workers were simultaneously dependent upon each other for subsequent progress and independent as they carried out their assigned tasks. Representative comments included, 'Everybody is doing something and everybody has a piece of equipment they are working with'; and, 'They were all connected with the part they were working on, but everybody had their own job.'

When students were asked what they had learned about the interaction between people, materials, and tools on a construction site, most noted that they recognized the tools used on the site, but were surprised by what they learned about the amount and type of interaction between people, tools, and materials. Students reported learning that organization on a site was critical. For example, students commented, 'They had a good stock pile . . . and a lot of stuff early on . . . It just makes you want to think in terms of long term goals. Where are you going tomorrow and how are you going to prepare for that?'; 'The material were laid out on specific areas . . . and it seemed to be very organized'; 'Most of the material had a predetermined location . . . no one had to wait for materials'; 'They had the crane so it could reach the entire site so that they didn't have to move it. That was really efficient, because it takes a long time to move a crane'; and, 'In watching the concrete truck come in, it has to leave access for all the other trucks to get into the site. So if two trucks come at once, one went to one side, the other went to the other; it got harder as they got more and more trucks and stuff built.'

Student interview responses suggested that students gained a significant degree of insight into a wide variety of safety issues associated with an active construction site. Safety comments included, 'I was surprised to see all the safety measures . . . every single one of the rebars had caps on them'; 'They have safety things for the workers and different things to protect the tools'; 'I went down after hours and saw . . . a welder kit raised on a crane. I guess you just have to take precautions and take good care of your stuff.'

Students were also able to identify a wide variety of sustainable development and environmental issues associated with the site, including the need for workers to maintain erosion control and sediment control. Students' comments indicated they were cognizant of the impact of the construction site on the surrounding air quality, noise level, and traffic flow, and that they recognized that engineers need to understand that there is impact from construction not only on the site itself but within the surrounding area.

Most students noted that time is very valuable on a construction site, but sometimes the need arises for additional time to be added to the schedule. During the semester in which their observations were conducted, the site experienced the effect of three large storms that had been downgraded from hurricanes. This provided students with the opportunity to observe site workers manage storm water and the effects of wind, and care for themselves and equipment under adverse conditions. In addition, the intense impact of this weather forced students to consider how the entire site was affected from requisite rescheduling and unavoidable down time. Representative student comments included, 'The weather played a big key. As it got better, they worked longer hours . . . weather was a huge part of the schedule of the job'; 'After the rain delays you could tell they really had a lot of construction to catch up on'; 'The real important things you saw come out were timing, and how the weather impacted everything.'

DISCUSSION

Based on the results of the survey in 2003, its validation in the 2004 trial, and interviews conducted in 2004, the field journal assignment appears to be a very effective tool in increasing perceived competency for the twelve skills itemized. It seemed to be particularly effective in the perception of competency in construction engineering skills for the students involved. Since the University of South Carolina does not have a

separate construction engineering field of study in the Civil and Environmental Engineering Department, it was expected that the students would not have significant exposure to construction activities and that this additional exposure to construction practices in land development would be very meaningful to students taking the courses in land development and sustainable construction.

The skill rating that improved most significantly in both years was the students' perception of their ability to estimate the human workforce needed for a construction activity. Since productivity is one of the most important factors affecting cost on a construction project that the project team should monitor and control, improvement of this skill is helpful in training future land development engineers [12]. Substantial perceived improvement in skill II-4, recognizing health, safety and environmental issues related to a construction activity, in both years is also a notable observation since there is substantial interest in including emerging issues relating to these topics in engineering education [7].

Although the second set of surveys served to validate the data collected the first year, there is still another validation concern that after substantial time has passed from the conclusion of the assignment, the students may rate themselves differently. Since most of the students involved are upper level undergraduate students, it is at this time difficult to give a third survey a year or so later. If there are more junior level undergraduates in future classes, it is recommended that a third follow-up survey be given in their senior year for further validation.

Based on the first year students' remarks, the assignment in the second offering was modified such that there were fewer entries of longer length. This was introduced in the second year and the results of the second survey set indicate that the students felt that they had improved their skills in almost all the categories as well as had those in the first year, and with fewer complaints about the time and effort involved in the assignment. It is therefore recommended that the assignment frequency and requirements remain as given in the second year. This will also help reduce travel accessibility issues to the construction site for students, when a suitable project is not as near by.

This assignment represented only about 10% of the effort and grade in a 3-credit upper level collegiate engineering course and yet the surveys indicate that there was a large increase in the self-ratings of the listed skills by the students. It is therefore recommended to keep using it as an educating tool for classes in land development engineering, sustainable development or other engineering courses relating to construction.

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APPENDIX: INITIAL AND FINAL SURVEYS

ECIV 570 Fall 2004-Initial Survey Last 4 digits of SS#_____

We are collecting data to evaluate the impact of the Field Journal assignment for engineering educational purposes. Your candid response will help evaluate this tool for future use in ECIV 570 and maybe other engineering courses.

Part 1: For each item please circle the response to indicate how well you feel you are able to implement the skill at this time.

	Not Yet Competent		Competent		Very Competent
Category I: Field Journal Skills					
1: Labeling journal for who, what, when, where:	1	2	3	4	5
2: Taking notes under variable field conditions:	1	2	3	4	5
3: Field sketching:	1	2	3	4	5
4: Observing details:	1	2	3	4	5
5: Recording details:	1	2	3	4	5
6: Reporting information objectively and with integrity:	1	2	3	4	5
Category II: Construction Engineering Skills					
1: Sequence the steps needed to perform a construction activity (ca):	1	2	3	4	5
2: Estimate the human workforce needed for a (ca):	1	2	3	4	5
3: Describe the tools/equipment needed to perform a (ca):	1	2	3	4	5
4: Recognize health, safety and environmental issues related to a construction activity:	1	2	3	4	5
5: Estimate the time needed to perform a construction activity:	1	2	3	4	5
6: Visualize how the item under construction might appear on a plan:	1	2	3	4	5
Have you worked on a job where you've had to take field journal notes? (circle one)			YES	NO	
If YES, please describe.					

Imagine you are an experienced civil engineer project manager asking a new engineer to take field notes. What suggestions might you give them so that they bring back good information? Please elaborate.

ECIV 570 Fall 2004-Final Survey Last 4 digits of SS#_____

We are collecting data to evaluate the impact of the Field Journal assignment for engineering educational purposes. Your candid response will help evaluate this tool for future use in ECIV 570 and maybe other engineering courses.

Part 1: For each item please circle the response to indicate how well you feel you are able to implement the skill at this time.

	Not Yet Competent		Competent		Very Competent
Category I: Field Journal Skills					
1: Labeling journal for who, what, when, where:	1	2	3	4	5
2: Taking notes under variable field conditions:	1	2	3	4	5
3: Field sketching:	1	2	3	4	5
4: Observing details:	1	2	3	4	5
5: Recording details:	1	2	3	4	5
6: Reporting information objectively and with integrity:	1	2	3	4	5
Category II: Construction Engineering Skills					
1: Sequence the steps needed to perform a construction activity (ca):	1	2	3	4	5
2: Estimate the human workforce needed for a construction activity:	1	2	3	4	5
3: Describe the tools/equipment needed to perform a (ca):	1	2	3	4	5
4: Recognize health, safety and environmental issues related to a construction activity:	1	2	3	4	5
5: Estimate the time needed to perform a construction activity:	1	2	3	4	5
6: Visualize how the item under construction might appear on a plan:	1	2	3	4	5

After completing the journal assignment, do you feel that your answers to the preliminary questionnaire about your skill levels may have been incorrect? Why?

Please write down any comments/suggestions you have about the field journal assignment.

Thank you