Review Design of Concrete Structures: Evaluating Learning Effectiveness

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***Abstract*— The purpose of this study is to analyze learning effectiveness when students are in training to review the design of concrete structures. Two different course delivery methods for vocational engineering students are compared. The first delivery method begins with a traditional instructional approach followed by an active learning approach. The second delivery method utilizes the same approaches, but in reversed order. The difference in learning effectiveness of the two approaches is analyzed, based on a semi-quasi pre-test/post-test experiment design with an experimental group (first hands-on, then theory) and a control group (first theory, then hands-on). Based on 30 test questions and difference scores between pre-test and two post-tests, as well as statistical significance and effect size, the learning effectiveness is determined. It was found that the learning effectiveness for both experimental and control group was higher during the hands-on approaches. When comparing the second post-test with the first post-test, the experimental group had only 2 positive difference scores, whereas the control group had 13 positive difference scores. The findings indicate that students need sufficient initial theoretical background in order to benefit from a hands-on approach.**

Keywords—learning effectiveness; concrete structures, design review, active learning

I. Introduction

Active learning has consistently been found more effective than lecturing [1]. The positive impact of various forms of active learning on engineering students' learning effectiveness has been shown in detail in different contexts. For example, it has been demonstrated that, with proper planning and sequencing of topics, it is possible to integrate and hence enhance engineering dynamics modeling courses using hands-on programming skills, leading to increased learning effectiveness [2]. Integrating Computational Fluids Dynamics (CFD) into a traditional fluid mechanics course has shown that the inclusion of hands-on CFD laboratories gave students a better appreciation of fluid mechanics in general and the students gained better knowledge of simple concepts [3]. Also a mechanical engineering design course has been developed, which actively engaged students and provided a hands-on project which stimulated students' interest and provided them with sufficient time to develop important engineering skills [4].

Finally, an active learning environment, such as Project-Based Learning (PBL), has been shown to have a positive effect on students' perception of their personal responsibility for learning [5]. Perceiving personal responsibility for learning is a trait which is of high importance for students' learning in general and, considering that incorrect reviews of concrete design may lead to fatal consequences, is of particular importance for students learning to review design of concrete structures.

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II. Learning "Design of Concrete Structures"

Active learning and hands-on approaches in courses related to the design of reinforced concrete structures are not new.

Reference [6] reported positive reactions of students regarding their hands-on concrete laboratory experience. Students' feedback was collected through end-of-semester surveys. Reference [7] found that students' designing, building and testing of a reinforced concrete beam led to an improved understanding of concrete fundamentals and an enhanced learning. In line with the previous study [7], this observation was confirmed by students' feedback. Reference [8] observed that students demonstrated a high level of understanding of engineering principles and design concepts, after they had built and tested a reinforced concrete beam.

A Student Experiential Learning Centre (SELC) for undergraduate laboratory testing was initiated, in order to allow students to carry out independent and unsupervised laboratory work after they received relevant instructions [9]. An increase of students' responsibility for their learning, improved students' skills, and students' perception that they benefited from the learning experience were observed. Second year students of a course related to reinforced concrete structures used the SELC approach and, based on observations and anecdotal evidence, students felt that it enabled them to learn about the behavior of reinforced concrete [9]. In a similar approach, students were responsible for conducting parts of concrete laboratory sessions with minimal supervision. Consistent with the previous studies, a high level of active learning was observed [10].

Reference [11] reported that the integration of the following three methods enhanced students' comprehension and retention of concrete design skills:

- Use of a concrete building code;
- Application of programming exercises; and,

- Full-scale design, construction and testing of a reinforced concrete beam.

However, so far it has not been identified if a comprehensive hands-on approach to building a concrete structure has a positive learning effect on reviewing designs of concrete structures. Furthermore, it is still unclear if and how different modes of content delivery influence each other. In the next section, the purpose of this study will be described in more detail, followed by method, results, discussions and conclusion sections.

III. Purpose

The purpose of this study is the analysis of the effectiveness of learning “reviewing concrete design”, when using two different delivery methods.

The first delivery method begins with a period of traditional teaching that focusses on theory (in the following called “theory”), followed by a period of active learning based on a hands-on project (in the following called “hands-on”). The second delivery method combines the same approaches, but in reverse sequence: It begins with a period of hands-on learning, followed by a period of theory-focused learning. It can be expected that one of these two delivery methods leads to a higher learning effect, since each delivery method utilizes a different approach to reinforce previous learning.

IV. Method

Methodologically, learning effectiveness can be analyzed by carrying out semi-quasi pre-test/post-test experiments with an experimental group of students and a control group of students. This approach has been applied successfully in various contexts before [12], [13].

A. Experimental and Control Group

For this study, the experimental group (i.e. first hands-on, then theory) consisted of 25 students, and the control group (i.e. first theory, then hands-on) consisted of 33 students. All students were students of civil engineering in their fourth semester at a private college in the Middle East. The experimental group included two students with work experience related to concrete structures, and the control group included one student with work experience. Both groups were also comparable regarding gender mix, average age and the average grade (experimental group: 86.7%, control group: 86.3%). Both groups were taught by the same instructors who coordinated the delivery of teaching material in order to ensure learning of the same learning outcomes. Following good teaching practice, the instructors alternated theory input with time for reflection and activities in order to optimize students' learning process [14]. The instructors allowed a similar amount of time for reflection during both approaches (i.e. theory and hands-on), whereas students had obviously more time for activities during the hands-on approach. Therefore, potential group bias is considered to be controlled.

B. Course Description

The course considered here is “RIICWD533A - Prepare detailed design of civil concrete structures” as published by the National Register on Vocational Education and Training (VET) in Australia [15]. It is part of the curriculum “Diploma of Civil Construction Design” and is delivered over a period of 13 weeks with five contact hours per week. The course includes 19 learning outcomes that are organized into four groups:

1. Plan for the detailed design of civil concrete structures;
2. Undertake the detailed design of civil concrete structures;
3. Finalize design processes of civil concrete structures; and,
4. Support and review the application of the design of civil concrete structures.

The following learning outcomes belong to the fourth group of learning outcomes:

1. Provide clarification and advice to those applying the design;
2. Review the application of the design and recommend changes for the continuous improvements of civil concrete structures detailed designs; and,
3. Contribute to the validation of the design [15].

It is the second of these learning outcomes, “Review the application of the design and recommend changes for the continuous improvements of civil concrete structures detailed designs” (in the following called “Review Design of Concrete Structures”), that is considered here. Although this learning outcome is not an explicit learning outcome in all civil engineering curricula, it can be considered an implicit learning outcome in all diploma and degree level courses related to reinforced concrete structures, since students need to learn to identify shortcomings in concrete design.

C. The Hands-on Project

The hands-on project consisted of building a reinforced concrete frame consisting of two columns, each based on a column footing, and connected by a beam. The dimensions are shown on Fig. 1.

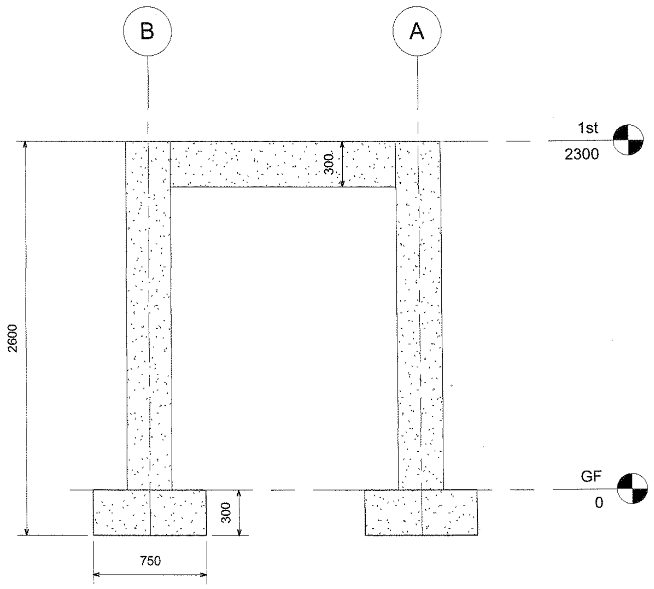

Fig. 1. Dimensions of concrete frame

Based on provided structural drawings, students had to:

- Erect formwork using proprietary formwork elements;
- Produce and install the reinforcement cages;
- Prepare spacers;
- Participate in casting supplied ready mixed concrete (Fig. 2);
- Remove (strip) formwork; and,
- Cure concrete.

Students had seven five-hour sessions available and received assistance from the instructors and a lab technician. At appropriate points of time, the instructors explained the aspects that were covered by the pre- and post-tests in a similar manner to that used during the theory sessions.

Fig. 2. Students casting concrete for footings

D. Pre- and Post-tests

A pre-test was administered to all students in Week one, in order to identify their competencies in reviewing design of concrete structures at the beginning of the course. A first repetition of the same test (in the following called "first post-test") took place in Week seven, when the experimental group finished their hands-on project and the control group finished their theory component. A second repetition of the same test was administered in Week 13, when the experimental group finished their theory component and the control group finished their hands-on project. Students were not informed that the test with the same questions would be administered repeatedly throughout the semester. However, they were informed at the beginning of each test that the test was not part of the assessment items for this course and that it had no influence on their grades; rather, it presented an additional opportunity for them to identify their current competencies related to reviewing concrete design. All students being present on the test days used this opportunity and participated. The test consisted of 30 True/False questions, Q1 to Q30, and did not include questions that were part of course assessment items. An example question is shown on Fig. 3.

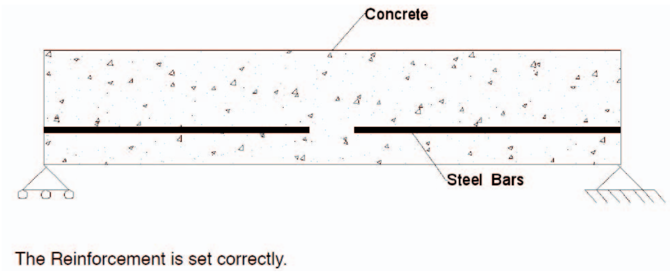

Fig. 3. Example of True/False test question

E. Analysis

In order to analyze the collected data and utilizing a binary scale, students' answers were encoded with "1" for a correct answer and "0" for an incorrect answer. For the descriptive statistics, the mean value, median value and standard deviation were computed for each question result as well as for the difference scores between preceding and succeeding tests.

In order to test if there is a significant difference between pre- and post-test results, a one-tailed t-test for paired samples was carried out since only test scores within the same group were compared [16]. This was carried out for the tests with more than 50% positive difference scores, i.e. the first and second post-test of the control group as shown below in the results section. Although results of t-tests are quite robust against violating the assumption of a normal distribution, results are strongly influenced by outliers [12]. Therefore, the existence of outliers has been analyzed, and it was found that all scores of these two tests are within +/- 2 standard deviations around the mean score, except for question Q29 of the second post-test. Following common practice for situations where effect size and sample size cannot be increased and a low risk of error is aimed for, it was decided to set $\alpha = 0.1$ [17].

Information about the effect size has been added since statistical significance on its own has been proven to be insufficient, since a high statistical significance can either be a consequence of the sample size or of the coefficient (c.f. references in [18]). Following [19], the effect size has been computed by using Cohen's d, with the range of 0 to 0.20 indicating a weak effect, 0.21 to 0.50 a modest effect, 0.51 to 1.00 a moderate effect and larger than 1.00 indicating a strong effect of the treatment [18].

V. RESULTS

A summary of the descriptive statistics results of the two groups of students is given in Table 1 which presents the average values for mean, median and standard deviation. Students of the experimental group scored highest in the 1st post-test (average mean: 0.38), and students of the control group scored highest in the pre-test which was also the highest of all tests carried out (average mean: 0.41).

TABLE I. SUMMARY OF DESCRIPTIVE STATISTICS OF TEST SCORES

	Experimental Group			**Control Group**		
	Ave Mean	*Ave Median*	*Ave SD*	*Ave Mean*	*Ave Median*	*Ave SD*
Pre-test	*0.37*	*0.33*	*0.25*	*0.41*	*0.37*	*0.20*
1st post-test	*0.38*	*0.33*	*0.24*	*0.39*	*0.30*	*0.24*
2nd post-test	*0.34*	*0.30*	*0.22*	*0.39*	*0.27*	*0.21*

A summary of the descriptive statistics of difference scores for the tests carried out is shown in Table 2. For the experimental group, the number of positive difference scores (labeled "# pos. scores") decreases from 15 for the difference between pre- and post-test, to 13 for the difference between pre- and 2nd post-test, to 2 for the difference between 1st post- and 2nd post-test. For the control group, the number of positive difference scores decreases initially from 12 to 10, before it increases to 13. For the average mean values, all means are negative except the mean for the difference scores between 1st post-test and 2nd post-test of the control group, and except the mean for the difference scores between pre- and 1st post-test for the experimental group.

TABLE II. SUMMARY OF DESCRIPTIVE STATISTICS OF DIFFERENCE SCORES

	Experimental Group				**Control Group**			
	# pos. scores	Ave Mean	Ave Median	Ave SD	# pos. scores	Ave Mean	Ave Median	Ave SD
Pre- vs. 1st post-test	15	0.02	0.00	0.57	12	-0.02	0.00	0.63
Pre- vs. 2nd post-test	13	-0.02	0.00	0.58	10	-0.02	0.00	0.62
1st post- vs. 2nd post-test	2	-0.04	0.00	0.56	13	0.00	0.00	0.61

Since the numbers of positive difference scores indicate a change of trend for the control group from 1st to 2nd post-test, a one-tailed t-test has been carried out and the results are summarized in Table 3. In addition to the t-value, the effect size (Cohen's d), degree of freedom (df), the critical t for $\alpha = 0.1$ and the probability of having a more negative t-value (for $t < 0$) or a more positive t-value (for $t > 0$) are shown. The difference between the 1st and 2nd post-test shows a statistical significant result with a moderate effect for variable Q11. For three further variables, namely Q18, Q22 and Q29, statistical significant results with modest effects were found. These results will now be discussed in the following discussion section.

TABLE III. RESULTS FOR 1ST POST-TEST VERSUS 2ND POST-TEST FOR THE CONTROL GROUP

	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
d	-0.06	-0.39	0.20	-0.25	0.14	-0.30	-0.26	0.12	-0.07	-0.07
df	32	32	32	32	32	32	32	32	32	32
t-	-0.24	-1.56	0.78	-0.96	0.58	-1.18	-0.96	0.54	-0.30	-0.28
Crit.*t*	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31
P	0.40	0.06	0.22	0.17	0.28	0.12	0.17	0.30	0.38	0.39

	Q11	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**	**Q18**	**Q19**	**Q20**
d	0.75	0.27	-0.14	0.00	-0.13	0.08	-0.16	0.36	-0.38	0.22
df	32	32	32	32	32	32	32	32	32	32
t-	2.98	1.09	-0.54	0.00	-0.58	0.28	-0.71	1.43	-1.82	1.02
Crit.*t*	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31
P	0.00	0.14	0.30	0.50	0.28	0.39	0.24	0.08	0.04	0.16

	Q21	**Q22**	**Q23**	**Q24**	**Q25**	**Q26**	**Q27**	**Q28**	**Q29**	**Q30**
d	0.00	0.42	-0.14	0.06	0.00	0.00	-0.13	0.07	0.38	0.06
df	32	32	32	32	32	32	32	32	32	32
t-	0.00	1.55	-0.58	0.24	0.00	0.00	-0.47	0.26	1.46	0.26
Crit.*t*	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31
P	0.50	0.07	0.28	0.40	0.50	0.50	0.32	0.40	0.08	0.40

VI. DISCUSSION

For both the experimental and control groups when comparing hands-on and theory deliveries, the learning effect was higher during the hands-on delivery.

For the experimental group (first hands-on, then theory), the mean values (Table 1) of the three tests indicate that the hands-on project had a positive effect in the short run, but it seems that this could not be sustained during the period of the theory delivery. This led to a decreased mean value of 0.34 in the 2nd post-test.

A similar effect is apparent for the control group (first theory, then hands-on). The decrease in mean value from 0.41 to 0.39 indicates that no learning of reviewing concrete design had taken place during the period of the theory delivery. However, the learning effect was higher during the hands-on project as indicated by the constant mean value of 0.39 in the 1st and 2nd post-tests.

The relative low learning effectiveness for both groups of students may reflect the students' background which emphasizes rote learning, as identified in an earlier study [20]. Different from what students were accustomed to, students had no review-sessions prior to the experimental tests. Furthermore, when the instructors explained aspects relevant for the experimental tests during the theory sessions or the hands-on sessions, students were neither encouraged to memorize these aspects, nor were they informed that these aspects are part of an experimental test. Finally, students may not have taken these tests serious because they knew that the tests did not contribute to their course grades. This may also explain why learning "reviewing concrete design" decreased over the semester (as reflected by an overall decrease of mean values). Students were more concerned with their course grades towards the end of the semester than at the beginning.

The highest number of positive difference scores (Table 2) was identified for both groups during the hands-on delivery. This indicates higher learning effectiveness during the hands-on delivery and confirms the previous interpretation of mean values of the experimental tests.

However, the groups show different trends of positive differences scores when comparing the 1st post-test with the 2nd post-test: The experimental group improved only in two of the 30 questions (after improving in 15 questions during the hands-on delivery), whereas the control group improved in 13 questions (after improving in 12 questions during the theory delivery). This may indicate that for the control group the earlier learned theory was helpful for students during their hands-on project, whereas for the experimental group the earlier hands-on project did not positively affect their learning based on theory sessions.

When looking at the four questions that improved significantly during the hands-on delivery of the control group (i.e. Q11, Q18, Q22 and Q29; Table 3), the following can be said.

For question Q11, students had to identify if all necessary dimensions were shown. They had learnt this aspect during the theory delivery before, and the aspect was reinforced during the hands-on delivery. For question Q18, students had to understand that slab-joints require adequate support. Although this aspect was not directly related to the hands-on project (i.e. students did not have to build a joint), the project may have reinforced their understanding of the importance of adequate supports of concrete elements. For question Q22 students had to understand that the shape of concrete design needs to allow removal of formwork without damaging the formwork. The project may have reinforced this aspect although the situation depicted in their experimental tests was somewhat different from the project. Question Q22 was related to the concrete mix design and was directly related to students' project activities. Hence, two of the four questions were directly related to students' activities and two were more indirectly related to their project.

The result indicates that the project supported also students' learning regarding aspects that were not explicitly built by the students; rather these aspects were explained by the instructors based on the project. Since all aspects were also covered during the previous theory delivery, the hands-on delivery reinforced students' learning and improved their learning effectiveness.

In summary, the results confirm earlier findings in that the absolute learning for both groups was higher during the hands-on project than during theory sessions. In addition, preceding theory-focused learning seems to contribute to a broader learning (i.e. learning more aspects) during the hands-on project. Finally, the hands-on projects supported also learning aspects that were indirectly related to the project. These aspects were not physically built by the students, but they were explained by the instructors based on the project.

VII. VALIDITY AND FUTURE RESEARCH

The following can be said concerning the validity of the experiment.

The construct validity was given by implementing various measures to counteract "memorizing without understanding", since the test questions were designed to measure learning and not "memorizing without understanding". First, students were not informed about the repetitions of the experimental tests. Second, when teaching aspects relevant for the experimental tests, the instructors did not inform students about the relevance for experimental tests. Third, aspects relevant for the experimental tests were not part of any regular assessment item and, therefore, were not covered in any review-session. Fourth, the instructors did not provide any feedback on the experimental tests before the 2nd post-test was delivered.

The pre-test/post-test experimental design, applied to an experimental group and a control group, eliminated distortion of results that may have threatened the internal validity. Furthermore, a maturation effect was avoided by not informing students about repetition of the same experimental tests.

Regarding the external validity, it can be expected that the results are valid for the socio- economic context of the students who were studied here. Different contexts may lead to different results.

In order to confirm these results, a replication of the experiment will be carried out.

VIII. Conclusions

In order to evaluate the learning effectiveness of reviewing concrete designs, experiments were carried out. Utilizing a pre-test/post-test experiment design with an experimental group (first hands-on, then theory) and a control group (first theory, then hands-on) of students, it was found that for both groups the learning effect was higher during the hands-on approach. However, it was also found that the theory-focused learning contributed to learning more aspects during the hands-on approach. This indicates that students need to have some theoretical background in order to benefit more from a hands-on project. Furthermore, the hands-on delivery seems to support also learning aspects that are not directly related to students' activities, but were explained based on the hands-on project. Experiment replications that include a strategy to increase students' seriousness of the experimental tests are necessary in order to increase the construct validity of the experiment and to confirm the findings presented here.

References

[1] R.M. Felder, D.R. Woods, J.E. Stice, and A. Rugarcia, "The future of engineering education II: Teaching methods that work," Chem. Engr. Education, vol. 34(1), 2000, pp. 26-39.

[2] D. Adair and M. Jaeger, "Developing programming skills to enhance engineering dynamics modelling," Proceedings of IETEC'11 Conference, 16-19 January, 2011, Kuala Lumpur, Malaysia.

[3] D. Adair and M. Jaeger, "Integration of computational fluid dynamics into a fluid mechanics course," Computer Applications in Engineering Education, vol. 22(1), 2011, pp. 131-141.

[4] D. Adair and M. Jaeger, "An integrated centrifugal pump rotor design course," 4th Interdisciplinary Engineering Design Education Conference (IEDEC), Santa Clara, CA, 10-11th March, 2014, pp. 6-11.

[5] M. Jaeger and D. Adair, "The influence of student interest, ability and personal situation on student perception of a problem-based learning environment," European Journal of Engineering Education, vol. 39(1), 2014, pp. 84-96.

[6] A.C. Estes, D.E. Sibert, and C.H. Conley, "Using a realistic hands-on laboratory program to enhance a reinforced concrete design course," ASEE Annual Conference and Exposition, 2002.

[7] D. Cleary, "Enhancing a reinforced concrete design course by linking theory and physical testing," ASEE Annual Conference and Exposition, 2006.

[8] H. Jackson, K. Tarhini, B. Maggi, and N. Rumsey, "Improving students understanding of engineering concepts through project based learning," In Frontiers in Education Conference (FIE), IEEE, October 2012, pp. 1-6.

[9] L.A. Dawes, M.H. Murray, and G.N. Rasmussen, "Student experiential learning," In: 4th ASEE/AaeE Global Colloquium on Engineering Education, 26 September 2005, Sydney.

[10] A. Phelps, L. Sliger, S. Degracia, and S. Ganzerli, "Integration of new teaching methodologies into a laboratory based course," Structures Congress, 2008, pp. 1-11.

[11] N. Rumsey, J. Russell, and K. Tarhini, "Innovative approach to teaching undergraduate reinforced concrete design," In Frontiers in Education Conference (FIE), IEEE, October 2010, pp. T1C-1.

[12] D. Pfahl, O. Laitenberger, G. Ruhe, J. Dorsch, and T. Krivobokova, "Evaluating the learning effectiveness of using simulations in software project management education: results from a twice replicated experiment. Information and Software Technology, vol. 46, 2004, pp. 127-147.

[13] M. Jaeger and D. Adair, "Communication simulation in construction management education: Evaluating learning effectiveness," Australasian Journal of Engineering Education, vol. 18(1), 2012, pp. 1-14.

[14] R.M. Felder and L.K. Silverman, "Learning and teaching styles in engineering education. engineering education," vol. 78(7), 1988, pp. 674-681.

[15] NRVET. "RIICWD533A Prepare detailed design of civil concrete structures," National Register of Vocational Education and Training, https://training.gov.au/Training/Details/RIICWD533A, assessed 5 May 2014.

[16] D.J. Sheskin, Handbook of Parametric and Nonparametric Statistical Procedures, Boca Raton: CRC Press, 1997.

[17] M. Lipsey, Design Sensitivity, Beverly Hills, CA: Sage, 1990.

[18] L. Cohen, L. Manion, and K. Morrison, Research Methods in Education. Oxon, UK: Routledge, 2011, pp. 616-617.

[19] D. Muijs, Doing Quantitative Research in Education with SPSS, London: Sage, 2004.

[20] M.J. Webb, "Humanities and social science courses in undergraduate engineering curricula: The case of the Arabian Gulf," European Journal of Engineering Education, vol. 33(3), 2008, pp. 367-380.