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Development of a Supplemental Evaluation for Engineering Design Courses

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ABSTRACT

Compared to the learning that occurs in most engineering courses, the learning that occurs in design courses is more dependent on students, and less dependent on instructors. Because typical course evaluations are instructor-centric and do not provide information about students' contributions to their learning, we developed a supplemental evaluation to assess student actions and attitudes important to a quality design experience. We detected statistically-significant, logical shifts in self-reported practices and attitudes as student cohorts progressed through design projects. Factor analysis showed that the evaluation questions could be grouped into eight thematic categories, with most of the questions assessing student ability to function independently in uncertain situations, self-perception of maturation and achievement, and acceptance of responsibility for learning. Accepting responsibility for learning and believing that design experiences helps transition from being a student to being a professional were correlated with high student ratings of overall instructor performance and overall learning experience.

Keywords: design, assessment, professional skills, evaluations of teaching.

INTRODUCTION

Design courses are, in many respects, different from other engineering courses. While students may consider traditional courses as discrete or compartmentalized "units" of learning or concepts, design experiences overtly require students to draw from and apply multiple types of accumulated experiences and knowledge. Design courses require students to complete a project that is usually larger than students have previously completed, with continued student effort over a longer period of time than typical class projects, and with more process documentation than students are accustomed to providing. Furthermore, design problems are open-ended, and the projects are, in large part, student-driven. In helping students meet these challenges, design instructors guide the transition from operating as a student to operating as a professional.

The factors that make design courses challenging for students also make design courses challenging for educators. Design instructors must draw from a wide range of experiences and knowledge to provide guidance to students in multiple technical areas and in project management. Compared to instructors of traditional lecture courses, design instructors often spend more time interacting with students one-on-one or in small groups. Design instructors who teach multi-course sequences invest their effort in developing the abilities of their students over a longer period of time than do instructors whose course enrollments change from term to term. Perhaps the most important challenge of instructing a design course is achieving the fine balance between providing specific assistance/guidance and allowing students to direct their design process and make (and learn from) mistakes as they navigate the open-ended nature of the problem. In order to let the students "learn by doing," design instructors must relinquish some control of the learning process to the students, while still maintaining high standards for the quality of the project deliverables. Compared to the learning that occurs in traditional engineering courses, the learning that occurs in design courses is more dependent on students and their self-directed activities.

Many academic institutions use formal student evaluations of teaching to obtain feedback on perceived course quality and instructor performance. A good deal of research has demonstrated that student evaluations of teaching reflect student opinions validly, reliably, and usefully [1, 2, 3]. Traditional evaluation forms tend to be focused on the course instructor and their practices (*e.g.*, "Please rate the overall performance of the instructor," "The instructor gave well-organized lectures," "The instructor was well-prepared for class," *etc*.). These assessment items are most relevant to traditional lecture-based courses in which the instructor's actions and content organization largely set the pace and direction of student learning. However, these items do not provide information relevant to many of the special challenges faced by design students and instructors. Most notably, the instructor-centered nature of these evaluations provides little or no information about student contributions to their own learning.

The assessment of student design performance has been a focus of increased work over the last several years [4, 5, 6], including a coordinated effort undertaken by the Transferable Integrated Design Engineering Education Consortium [7]. This consortium has identified multiple roles and holistic behaviors of an engineer, including technical, interpersonal, and professional areas [7], and identified four broad areas (including, for example, learner development and solution development [8]) within which instructors could assess student performance. Programs seeking ABET accreditation must assess the design skills of their students, since some of the fundamental program outcomes criteria (*i.e.*, the "a through k" criteria) required by ABET are specifically focused on design [9]. Assessing the learning that occurs during complex tasks (involving many components/aspects, with complicated relationships between aspects [10]), such as the design process, is challenging. Non-traditional measures such as concept maps [11] or causal influence diagrams [10] may help instructors and programs measure how well students have mastered design skills. However, summative demonstrations of student skills and technical analyses of project deliverables, again, typically yield little or no information about how students are contributing to their own learning. Having an instrument that gives some indication of how engaged [12] students are in the learning-by-doing design process, and some indication of whether a fundamental level of independent metalearning (*i.e.*, learning about learning [13]), would be helpful to design instructors.

In order to assess some of the student actions and attitudes that are important to a successful design experience, but that tend not to be addressed through formal student evaluations of teaching or through typical course/program-related assessments of student design performance, we developed a supplemental design evaluation. We hoped the supplemental evaluation would provide information to design instructors seeking to better understand how students perceived the balance between receiving specific, overt project guidance and directing their own design processes and learning. We also hoped that correlational analysis of responses to various items on the evaluation would provide insight into self-reported attitudes and perceptions about design. This paper describes the development and administration of the evaluation, and briefly describes how evaluation results were used by design instructors to improve the design experience for students as well as to assess the evaluation itself for revision and future use.

METHODS

Supplemental Evaluation Instrument

The first version of our supplemental evaluation consisted of 25 questions regarding student practices, student responsibilities, and instructor roles. Because traditional student evaluations of teaching already provide information regarding student perceptions of the quality their educational experiences, and since we sought to obtain new types of information about the students' educational experiences, we avoided rating scales that described levels of quality. Instead the rating scales were designed to provide information about the prevalence of activities, amount of overt guidance provided, or perceived balance of responsibilities. For example, rather than asking students to rate the quality of the instructor's technical advice as excellent, good, fair, or poor, the supplemental evaluation asked:

"When you discussed design and technical issues with the instructor, they:

- told you exactly what you should do
- tried to convince you to take particular actions
- provided suggestions but did not make decisions for you
- listened to your concerns but gave no suggestions
- did not seem to understand your concerns and gave no suggestions."

Rating systems such as the scale shown above can be used as instructor goals change over the course of a design project or series of design courses. For example, an instructor might intend to give students more guidance early in the design experience, and less later on. The supplemental evaluation would be able to provide useful feedback to the instructor at both the early and late stages of the design experience. Other questions and types of rating systems that were intended to provide useful information throughout a design experience were, for example:

"Taking this course is helping me make the transition from being a student to being a professional.

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree."

"As this course/series of courses progressed, I had to make choices or decisions even though I didn't know everything there possibly was to know about an issue.

- Almost never
- Not very often
- Often
- Very often
- Almost every day."

The full supplemental design evaluation instrument used in this study will be downloadable from the *AEE* website as supplementary material for this paper.

Evaluation Administration

The supplemental design evaluation was administered in paper form to biomedical engineering and civil engineering seniors in their respective capstone design courses at Rose-Hulman Institute of Technology, at the conclusions of the Fall and Winter (civil engineering), and Fall, Winter, and Spring (biomedical engineering) 2006/2007 terms (IRB approved protocol #RHS0054). Brief descriptions of these design courses follow, to provide some understanding of the students' design activities:

during the Fall quarter, civil engineering seniors preferenced projects submitted by external clients. Teams then developed a written project proposal that summarized the client's goals and constraints, outlined their plan for identifying the problem and designing a solution, and confirmed the scope of work. The teams then spent the remainder of the Fall quarter and all of the Winter quarter investigating the client's needs, developing and evaluating options, and developing detailed designs for the selected options. During the Winter quarter, they were required to deliver an oral presentation and submit a written progress report to the client presenting their work thus far and seeking approval to design the recommended options. During the Fall quarter, teams of biomedical engineering seniors selected projects with corporate clients or individuals within the community, worked up at least three distinct design options, created and used merit and feasibility criteria to select one option, and completed a full design proposal for that option. During the Winter quarter the teams built and tested their designs, and wrote completed design documentation. The completed projects were delivered to clients early in the Spring quarter, and during this quarter the students served as mentors for teams of junior biomedical engineering students working through their first major design-build-test experience and completing their first design documentation. (Brief descriptions of the biomedical engineering design projects completed in 2006/2007 can be obtained separately from the AEE website.)

Student participation in the development of the supplemental design evaluation was anonymous, voluntary, and uncompensated. Supplemental evaluations were administered by a faculty member while the course instructors were out of the classroom. 100% of the students present in each class on the days of administration completed the evaluations as requested, yielding 30, 27, and 29 evaluations completed in the Fall, Winter, and Spring by biomedical engineering students (response rates ranging from 80% to 94% of the students registered for these courses) and 30 and 46 evaluations completed in the Fall and Winter by civil engineering students (response rates of 60% and 94% of the students registered for these courses). Because the biomedical and civil engineering capstone design experiences are multi-term, the supplemental evaluation instrument was completed multiple times by the same two populations of students.

Student responses to the evaluation items were numerically coded for quantitative analysis. For example, the responses "Almost Never," "Not Very Often," "Often," "Very Often," and "Almost Every Day" were numerically coded as −2, −1, 0, 1, and 2. Incorrectly-answered items (*e.g.*, an item left blank or an item with two different responses marked) were omitted from the data set. The responses were then investigated using correlational and factor analyses (principal components analysis with varimax rotation) in SPSS (v.11, SPSS, Inc., Chicago, IL). The numerical data were not normally distributed and did not meet the assumptions inherent in the (parametric) Pearson correlation coefficient [14], so the nonparametric Spearman's rho correlation coefficient was used in this investigation. Similarly, the nonparametric Mann-Whitney test was used to statistically compare differences between (numerically-coded) responses from different student groups.

The full supplemental evaluation instrument, as administered in 2006/2007, can be obtained separately from the AEE website.

RESULTS AND DISCUSSION

Upon examining the full set of data from all completed evaluations, we discovered that student responses to five pairs of evaluation items were moderately correlated (Spearman's rho > 0.5; Table 1). The observed correlations were logical, considering the items involved. For example, one might expect that a student who found themselves solving an unexpected problem might need to make choices or decisions even though they didn't know everything there was to know about that problem—those two student actions are likely to be correlated. One might also expect that students who believed a design course was helping them make a transition from being a student to being a professional would be proud of what they achieved in the class—those two student attitudes are likely to be correlated.

We detected statistically-significant shifts on a few evaluation items from the Fall student responses to the Winter student responses (*e.g.*, Table 2). Table 2 displays evaluation items for which the mean student response at the end of the Winter term was significantly different (or most nearly so) from the mean student response on that item at the end of the Fall term. The shifts displayed in Table 2 are logical given the pedagogical goals and practices of the instructors of the design

Evaluation Items	Correlation Coefficient
• I had to objectively evaluate the work of my peers • I had to objectively evaluate my own performance	0.77
• Taking this course is helping me make the transition from being a student to being a professional • If asked, you could clearly explain why design courses are a defining element of an engineering education	0.53
• I had to solve unexpected problems • I had to teach myself things in order to accomplish our tasks	0.52
• I had to solve unexpected problems • I had to make choices or decisions even though I didn't know everything there possibly was to know about an issue.	0.52
• Taking this course is helping me make the transition from being a student to being a professional • I'm proud of what I have achieved in this class	0.50

Table 1: Correlated evaluation items. Correlation coefficients are Spearman's rho; $n = 133$.

Student Population	Evaluation Item	Shift Direction in Item Responses *(from Fall to Winter)* Toward:	Significance (p value)
Biomedical engineering	As this course progressed, we received less assistance from instructors and took on more responsibility for our decisions and actions.	Stronger agreement	0.01*
	When you asked technicians/professors other than the instructor for help, they…	Showing student more of what to do	0.03*
	Learning from doing a project is a different process from learning from a book or notes. Who do you think is ultimately responsible for what you learn in this type of course?	More student responsibility	0.05*
	In this class, you had to accomplish tasks set by the instructor. Who do you think is responsible for what you achieved in this course?	More student responsibility	0.06
	In this course I was allowed to make mistakes and then learn from the consequences of those mistakes.	Stronger agreement	0.10
Civil engineering	As this course/series of courses progressed, we received less assistance and direction from instructors and took on more responsibility for our decisions and actions.	More strongly agreeing	0.06
	When you discussed design and technical issues with the instructor, they…	Less instructor direction	0.09
	As this course/series of courses progressed, I had to manage competing demands for resources and time.	Occurring more often	0.09

Table 2: Quantifiable shifts in student-reported practices or perceptions: Fall to Winter quarters. Significances calculated using the Mann-Whitney test; * $p \leq 0.05$; $n = 57$ for all biomedical engineering data except for the "When you asked technicians/professors other than the instructor for help, they" item, for which $n = 45$; $n = 76$ for all civil engineering data except for the "When you discussed design and technical issues with the instructor, they…" for which $n = 75$.

courses; overall, they tend toward students assuming more responsibility for their learning as their capstone design sequence progressed. In addition to detecting general overall trends, the supplemental evaluation was able to detect differences between the student populations: for example, the biomedical engineering but not the civil engineering student population reported having technicians provide more directed assistance over time, and the civil engineering but not the biomedical engineering student population reported having to increasingly manage competing demands for resources and time.

Many of the same supplemental evaluation items showed similar shifts from the Fall to the Spring administrations of the instrument (Table 3, Figure 1); responses to some evaluation items did not shift appreciably from quarter to quarter (Figure 1). After each administration, histograms of the student responses to each supplemental evaluation item were shared with the design course instructors. The evaluation results helped confirm for the instructors when course goals were being achieved (*i.e.*, frame A in Figure 1) and when improvements could be made (i.e., the responses in frame B of Figure 1 indicating a lack of pride). Because the evaluation was completed anonymously, it was not possible to correlate evaluation results with instructor-evaluated team performance or design quality. Seeking evidence of such correlations is one aspect of currently-ongoing work in this area.

Factor analysis showed that the supplemental design evaluation instrument contained questions that could be grouped into eight underlying factors or components that accounted for 73% of the variance in the data. Examining the individual items grouped within each factor, we were able to describe these factors as shown in Table 3.

The factor analysis revealed that some evaluation items were evidently understood by students in different ways than intended. For example, it appears that students may have considered the item "As this course/series of courses progressed, I had to separate personal issues from professional responsibilities when working in a team" to be asking whether difficult team conflict occurred, rather than asking about a normal part of professional teamwork. Many of the factors shown in Table 3 are important to how students are likely to respond to the open-ended, non-instructor-centric, self-learning nature of typical design problems. For example, a student who is uncomfortable dealing with unexpected situations or problems and who wants the instructor to serve as an

Evaluation Item	Shift Direction *(from Fall to Spring)* Toward:	Significance
When you asked technicians/professors other than the instructor for help, they…	Showing student more of what to do	0.005
In this course, I was allowed to make mistakes and then learn from the consequences of those mistakes	More strongly agreeing	0.009
As this course/series of courses progressed, we received less assistance and direction from instructors and took on more responsibility for our decisions and actions.	More strongly agreeing	0.062
Learning from doing a project is a different process from learning from a book or notes. Who do you think is ultimately responsible for what you learn in this type of course?	More student responsibility	0.072

Table 3: Quantifiable shifts in biomedical engineering student-reported practices or perceptions: Fall to Spring quarters. Significances calculated using the Mann-Whitney test; *n* = 59 for all data.

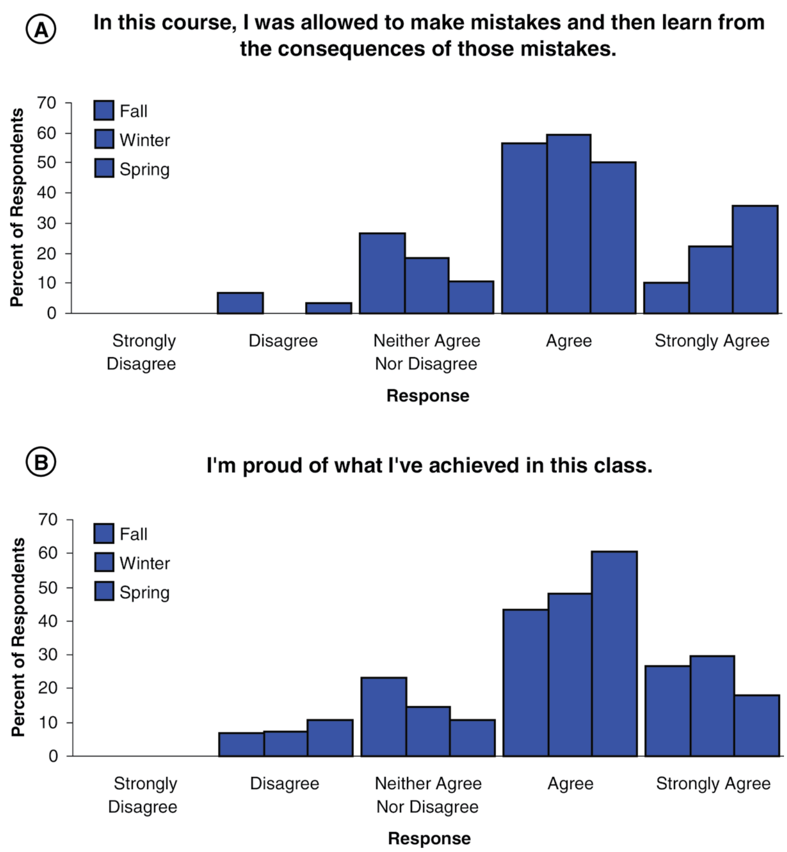

Figure 1: Histograms of longitudinal biomedical engineering student responses regarding learning from mistakes and taking pride in work. Data are reported as percent of respondents to each administration of the evaluation.

overtly directive authority figure is unlikely to enjoy the learning-by-doing aspect of design, and may therefore give design courses and instructors poor evaluations. To explore this possibility, in the Spring of 2006/2007 we added two questions to the end of the supplemental design evaluation, phrased exactly as are two key questions from the official institutional student evaluations of teaching: “Please rate the quality of your learning in this course,” and “Please rate the professor’s overall performance in this class,” (response choices for both questions were: Poor, Fair, Satisfactory, Very Good, or Excellent). As is standard practice with the official student evaluations, these answers were coded numerically to correspond to the integers 1 (“Poor”) through 5 (“Excellent”).

Some items on the supplemental evaluation were mildly to moderately correlated with student ratings of overall instructor performance and overall learning (Table 4). Table 4 provides evidence that students who believe they are learning from their design course and who believe the design

Factor	Description	Percent of Variance in Data Attributed to This Factor
1	Students' ability to independently handle situations as they arise	21.4
2	Students' self-perception of maturation and achievement	11.6
3	Students' dependence on the instructor as a guide	10.4
4	Students' dependence on assistance from others	7.7
5	Students' acceptance of responsibility for learning	6.7
6	Students' ability to handle uncertainty	5.6
7	Students' rejection of responsibility for learning	5.5
8	Students' motivation by the project or client	4.5

Table 3: Main underlying factors or components assessed in the supplemental design evaluation. The percent of variance attributed to each factor can be interpreted as a relative ranking of the importance of the factor—so, the underlying construct of students' self-perception of maturation and achievement explains more of the variation in the data than the construct of students' dependence on the instructor as a guide.

Correlated with rating of professor's overall performance	Correlation	Correlated with rating of quality of learning in the course:	Correlation
Rating of quality of learning in course	0.50	Rating of professor's overall performance	0.50
Strength of agreement with "Taking this course is helping me make the transition from being a student to being a professional"	0.43	Strength of agreement with "Taking this course is helping me make the transition from being a student to being a professional"	0.50
Strength of agreement with "If asked, you could clearly explain why design courses are a defining element of an engineering education"	0.39	Strength of agreement with "I'm proud of what I've achieved in this class"	0.46
Strength of agreement with "I'm proud of what I've achieved in this class"	0.37	Strength of agreement with "As this course/series of courses progressed, we received less assistance and direction from instructors and took on more responsibility for our decisions and actions"	0.44

Table 4: Supplemental evaluation items correlated with overall ratings of instructor performance and learning. Correlation coefficients are Spearman's rho; all correlation coefficients shown are statistically significant at the $p < 0.01$ level; $n = 29$.

experience is helping them transition from being a student to being a professional may be likely to rate their design courses and instructors better than students who do not believe they are learning and growing from the experience.

Student ratings of the professor's overall performance reported on the supplemental evaluation were generally similar to the student ratings of the professor's performance reported on the official institutional evaluation forms; the official ratings tended to be slightly higher (usually 0.1 or 0.2 points higher on the scale of 1 to 5). The official student ratings of their overall learning were either similar to or lower than the quality of learning reported on the supplemental evaluation. In one course section, the learning rating from the supplemental evaluation form was one full point higher (on the scale of 1 to 5) than the rating on the official evaluation. This was likely due to different response rates, and sampling error associated with small response rates: in this case, the response rate on the supplemental evaluation was 94% and the response rate on the (electronically-administered) official evaluation was 32%.

Information from the supplemental evaluation helped put student comments on the official teaching evaluations into a new context. For example, the following comments were submitted in response to 'Please rate the quality of your learning' in the official teaching evaluations:

> "This class didn't really 'teach' much information, more that it tried to help us use info we already had in a new way."
>
> "They have formatted the class so that the group is responsible for their own project design and decisions to make it work."

While these comments were associated with lower numerical ratings (and therefore interpreted as being 'negative' from the student perspective), these comments are encouraging to a design instructor. Design is the capstone experience for engineering students and does bring together previous material to undertake a larger project, and we do want students to recognize that they are responsible for their projects.

Information from the supplemental evaluation was used by course instructors as part of their continual improvement efforts. For example, in response to learning that some students appeared to not be taking ownership of their projects (and were also rejecting responsibility for their learning), changes were made in the next iteration of the course to explicitly discuss design as a defining feature of engineering, and to have students model aspects of professional behavior from the beginning (the Junior design course) instead of introducing this in the Senior Fall course. One of the most important of these aspects was having students sign all submitted documentation, and having related discussions of what their signatures mean about the their relationship to the submitted work (since their signature means they approve—as an engineer—of the entire contents). Information regarding student perceptions of their team's workload and handling of uncertainty indicated that many students saw their team as having to do more work and handle greater uncertainty than other teams. By relocating designated design project time to a large, common room where all teams work in the same area, students can see that other teams are facing similar challenges (if on very different projects), and this has increased their ability to work with uncertainty because they realize that it's part of the process. An unexpected, but correlated outcome for working in a common room in their teams is that students in the current design sequence recognized early on that classmates are resources (for information, ideas, etc.) and not competitors in design. Additionally, after learning from the supplemental evaluation results that some students did not feel proud of their work, the instructors made a concerted effort to give positive feedback and praise when the opportunity arose. Specifically, the instructors made an effort to praise students for their hard work and persistence, since literature reports indicate praise of this nature may encourage students to focus on learning goals (*e.g.*, "I want to figure this out.") rather than performance goals (*e.g.*, "I want to get an A in this class.") [15]. Students who operate from a learning-based orientation may respond better to academic challenge [16], such as the challenges inherent in design projects.

CONCLUSIONS

We have developed a supplemental design evaluation that can provide quantitative information about whether design instructors' goals are being met—for example, whether students are assuming more responsibility for their learning as the design experience progresses. The supplemental evaluation provides information that is not assessed by traditional student evaluations of teaching, or through grading/assessment of the technical quality of student-designed deliverables. The evaluation can be used by design instructors to better understand students' perceived independence, responsibility for learning, and prevalence of professional activities. Design instructors can then change aspects of their courses (more clearly explaining particular requirements, having different discussions about professional responsibilities, asking students to keep track of/reflect on various professional work practices, etc.) to encourage desired outcomes.

We are currently working on revising the initial version of the supplemental design evaluation by revising items that appear to be interpreted in multiple ways by students, and eliminating items that appear to obtain redundant information. We plan to add items related to an underlying factor of student self-assessment of the technical quality of their design product, and to add items to more clearly understand student orientations to challenge and ability to overcome academic difficulties [15, 16]). Our ultimate goal is to develop and disseminate a short, robust instrument that could be used to obtain information particularly relevant to design courses.

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BIBLIOGRAPHY

[1] Cashin, W.E.: Student Ratings of Teaching: The Research Revisited, IDEA Paper no. 32, September 1995, *Center for Faculty Evaluation & Development, Division of Continuing Education, Kansas State University*, Manhattan, Kansas; http://www.idea/ksu.edu, accessed August 2, 2006.

[2] Cohen, P.A.: Student Ratings of Instruction and Student Achievement: A Meta-Analysis of Multisection Validity Studies, *Review of Educational Research*, 51(3):281–309, 1981.

[3] Marsh, H.W.: Students' Evaluations of University Teaching: Research Findings, Methodological Issues, and Directions for Future Research, *International Journal of Educational Research*, vol. 11, 253–388, 1987.

[4] Campbell, S. and Colbeck, C. L.: Teaching and Assessing Engineering Design: A Review of the Research, *Proceedings of the American Society for Engineering Education Annual Meeting*, Seattle, WA, June 28–July 1, 1998.

[5] Trevisan, M., Davis, D., Beyerlein, S., Thompson, P., and Harrison, O.: A Review of the Literature on Assessment Practices in Capstone Engineering Design Courses: Implications for Formative Assessment, *Proceedings of the American Society for Engineering Education Annual Meeting*, Chicago, IL, June 18–21, 2006.

[6] Gibson, I.S.: Assessment Criteria for Undergraduate Project Work in Engineering Design, *European Journal of Engineering Education*, 23(3):389–395, 1998.

[7] Beyerlein, A., Davis, D. Trevisan, M., Thompson, P., and Harrison, O.: Assessment Framework for Capstone Design Courses, *Proceedings of the American Society for Engineering Education Annual Meeting*, Chicago, IL, June 18–21, 2006.

[8] Davis, D., Beyerlein, S., Harrison, O., Thompson, P., Trevisan, M, and Mount, B.: A Conceptual Model for Capstone Engineering Design Performance and Assessment, *Proceedings of the American Society for Engineering Education Annual Meeting*, Chicago, IL, June 18–21, 2006.

[9] ABET, Engineering Accreditation Criteria, 2007–2008 criteria, available online at http://www.abet.org/forms.shtml#For_Engineering_Programs_Only, accessed 10/22/07.

[10] Spector, J.M.: A methodology for assessing learning in complex and ill-structured task domains, *Innovations in Education and Teaching International*, 43(2):109–120, 2006.

[11] Walker, J.T., King, P.H.: Concept Mapping as a Form of Student Assessment and Instruction, *Proceedings of the American Society for Engineering Education Annual Meeting*, Montréal, Quebec, Canada, June 16–19, 2002.

[12] Bryson, C., Hand, L.: The Role of Engagement in Inspiring Teaching and Learning, *Innovations in Education and Teaching International*, 44(4):349–362, 2007.

[13] Jackson, N.: Developing the Concept of Metalearning, *Innovations in Education and Teaching International*, 41(4):391–403, 2004.

[14] Glantz, S.A.; Primer of Biostatistics, 4th edition, New York, New York: McGraw-Hill Health Professions Division, 1997.

[15] Mueller, C.M., Dweck, C.S.: Praise for Intelligence Can Undermine Children's Motivation and Performance, *Journal of Personality and Social Psychology*, 75(1):33–52, 1998.

[16] Benishek, L.A., Feldman, J.M., Shipon, R.W., Mecham, S.D., Lopez, F.G.: Development and Evaluation of the Revised Academic Hardiness Scale, *Journal of Career Assessment*, 13(1):59–76, 2005.

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