

## **2007: DEVELOPMENT OF A SUPPLEMENTAL COURSE EVALUATION FOR CAPSTONE DESIGN**

Kay C Dee, Rose-Hulman Institute of Technology

Kay C Dee is an Associate Professor of Applied Biology and Biomedical Engineering, and is the Founding Director of the Rose-Hulman Center for the Practice and Scholarship of Science, Engineering, and Mathematics Students.

Glen A. Livesay, Rose-Hulman Institute of Technology

Glen Livesay is an Associate Professor of Applied Biology and Biomedical Engineering, and, with Renee Rogge, developed and teaches the biomedical engineering capstone design sequence at Rose-Hulman.

Renee D. Rogge, Rose-Hulman Institute of Technology

Renee Rogge is an Assistant Professor of Applied Biology and Biomedical Engineering, and, with Glen Livesay, developed and teaches the biomedical engineering capstone design sequence and Rose-Hulman.

## Development of a Supplemental Course Evaluation for Capstone Design

### Abstract

Capstone design is, in many respects, different from other courses in that students undertake a large, often multi-term project, and must apply knowledge gained from previous courses to solve a problem. Design courses are challenging for many students because the problems are open-ended and the projects are student-driven. These aspects make design courses very different from traditional engineering courses, in which instructors often craft problems specifically to reinforce particular content/skills to be learned, and the instructor largely sets the pace and direction of student learning and activities. Compared to the learning that occurs in traditional engineering courses, the learning that occurs in design courses is more dependent on the student and less dependent on the instructor.

Student evaluations of teaching are the most common method of obtaining feedback on perceived course quality and instructor performance. Traditional evaluation forms, however, tend to be instructor-centered, and do not provide information about the students' contributions to their own learning. We are therefore developing a supplemental design evaluation, to be used as a tool for assessing some of the student actions and attitudes important to a quality design experience. We are avoiding rating scales that ask students to rate items as either good or bad. Instead we seek to provide information to the instructor about the prevalence of specific student practices and attitudes.

In this paper we report results from an initial investigation of the first version of our supplemental evaluation, which was administered at the end of the Fall and the Winter terms to biomedical engineering ( $n = 30$  Fall,  $n = 27$  Winter) and civil engineering ( $n = 30$  Fall,  $n = 46$  Winter) seniors in their respective capstone design courses. Using the supplemental evaluation, we were able to detect statistically-significant shifts from the Fall student responses to the Winter responses on a few evaluation items. These shifts were logical given the pedagogical goals and practices of the instructors of the design courses. Factor analysis showed that the evaluation instrument contained questions that could be grouped into eight underlying factors or components, with most of the evaluation items assessing the concepts of students' ability to function independently (in uncertain situations), students' self-perception of their maturation and achievement, and students' acceptance of responsibility and the source of their motivation for the work.

We are currently working on revising the supplemental design evaluation presented in this paper by: revising items that appear to be interpreted in multiple ways by students; eliminating items that appear to obtain redundant information; and adding items related to an underlying factor of student self-assessment of the technical quality of their design product. Our ultimate goal is to develop and disseminate a robust instrument that could be used to obtain feedback beyond that available from traditional instructor-centered course evaluations, with particular relevance to design courses.

## Introduction

Capstone design is, in many respects, different from other engineering courses. While students may consider traditional courses as discrete or compartmentalized “units” of learning or concepts, capstone design experiences overtly require students to draw from their accumulated experiences and knowledge. Capstone 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. Furthermore, the design problems are open-ended and the projects are student-driven. In helping students meet these challenges, design instructors guide the transition from student to 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 independent 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<sup>3,4,7</sup>. 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 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. The assessment of design performance has been the focus of work over the last several years<sup>2,8</sup>, and a coordinated effort has been undertaken by the Transferable Integrated Design Engineering Education (TIDEE) Consortium. They have identified multiple roles and holistic behaviors of an engineer, including technical, interpersonal, and professional areas<sup>1</sup>, and also proposed a conceptual model for capstone design in which four areas of performance (for potential assessment) are identified, including learner development and solution development<sup>5</sup>. While the assessment of design skills is certainly a critical aspect of capstone courses that is not captured through traditional course evaluations, we are developing a supplemental design evaluation intended to assess some of the student actions and attitudes important to a successful design experience, which could be used to provide additional feedback to design course instructors.

## Methods

We developed 25 questions regarding student practices in design, perceptions of student responsibilities, and perceptions of instructor roles. Because traditional student evaluations of teaching are typically focused on student perceptions of quality, we deliberately used rating scales based on the prevalence of activities or balance of responsibilities rather than rating scales that directly described levels of quality. For example, rather than asking students to rate the quality of the instructor's technical advice as good, fair, or poor, we 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

The rating scale shown above can be used even as instructor goals change within or throughout a design sequence. For example, an instructor might intend to give students more guidance early in the design experience, and less later on; our supplemental evaluation would provide useful feedback to the instructor at both early and late stages of the design experience. The full supplemental design evaluation instrument is provided as an Appendix to this paper.

The first version of 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 2006/2007 terms (IRB approved protocol #RHS0054). Participation was anonymous and voluntary. 100% of the students asked to complete the evaluations did so, yielding 30 and 27 evaluations completed in the Fall and Winter by biomedical engineering students, and 30 and 46 evaluations completed in the Fall and Winter by civil engineering students. Because the biomedical and civil engineering capstone design experiences are multi-term, both the Fall and the Winter administrations of the instrument were completed by the same 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<sup>6</sup>, 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.

## Results

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 correlations observed are logical, considering the content of the items involved.

Evaluation Items	Correlation Coefficient
<ul style="list-style-type: none"> <li>• I had to objectively evaluate the work of my peers</li> <li>• I had to objectively evaluate my own performance</li> </ul>	0.768
<ul style="list-style-type: none"> <li>• Taking this course is helping me make the transition from being a student to being a professional</li> <li>• If asked, you could clearly explain why design courses are a defining element of an engineering education</li> </ul>	0.534
<ul style="list-style-type: none"> <li>• I had to solve unexpected problems</li> <li>• I had to teach myself things in order to accomplish our tasks</li> </ul>	0.523
<ul style="list-style-type: none"> <li>• I had to solve unexpected problems</li> <li>• I had to make choices or decisions even though I didn't know everything there possibly was to know about an issue.</li> </ul>	0.516
<ul style="list-style-type: none"> <li>• Taking this course is helping me make the transition from being a student to being a professional</li> <li>• I'm proud of what I have achieved in this class</li> </ul>	0.503

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

We detected statistically-significant shifts from the Fall student responses to the Winter responses on a few evaluation items (*e.g.*, Table 2). These shifts are logical given the pedagogical goals and practices of the instructors of the design courses.

Student population	Evaluation Item	Shift Direction (from Fall to Winter) Toward:	Significance
Biomedical engineering	As this course progressed, we received less assistance from instructors and took on more responsibility for our decisions and actions.	Stronger agreement	0.014
	When you asked technicians/professors other than the instructor for help, they...	Showing student more of what to do	0.030
	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	0.048
	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	0.061
	In this course I was allowed to make mistakes and then learn from the consequences of those mistakes.	Stronger agreement	0.098

Civil engineering	Which of the following most accurately describes the learning environment in your design course?	Student-defined goals	0.028
	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	0.064
	When you discussed design and technical issues with the instructor, they...	Less instructor direction	0.089
	As this course/series of courses progressed, I had to manage competing demands for resources and time.	Occurring more often	0.093

**Table 2. Quantifiable shifts in student-reported practices or perceptions.** Significances calculated using the Mann-Whitney test;  $n = 57$  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  $n = 75$ .

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.

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.

## Conclusions

The correlations between evaluation items and observed shifts in student responses are logical, considering the content of the items involved. The factor analysis results revealed that some evaluation items may be understood by students in different ways than we intended. For example, it appears that students may be perceiving the item “As this course/series of courses progressed, I had to separate personal issues from professional responsibilities when working in a team” as an indicator of difficult team conflict rather than as a normal part of professional teamwork. We are currently working on revising evaluation items to clarify the text of items that the factor analysis showed to be related to multiple underlying factors or components. We also plan to eliminate some evaluation items that appear to yield redundant information. We plan to replace the redundant items with items intended to relate to an additional underlying factor of student self-assessment of the quality of their design product. We anticipate testing an updated and revised second version of the supplemental design evaluation over the upcoming academic year.

The results of our preliminary investigation show evidence that the supplemental design evaluation 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. Our supplemental design evaluation is, therefore, providing information that is not provided by traditional student evaluations of teaching or of courses but that is important to design instructors as they work to continually improve their design courses.

## Bibliography

1. 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.
2. 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.
3. 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.
4. 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.
5. 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.
6. Glantz, S.A.; Primer of Biostatistics, 4<sup>th</sup> edition, New York, New York: McGraw-Hill Health Professions Division, 1997.
7. 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.
8. 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.

## Appendix

### Supplemental Design Course Evaluation

For each item below, please choose the one answer that best characterizes your design experiences.

1. 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.

2. When you brought **team conflicts** to the attention of 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.

Not applicable.

3. When you asked **technicians or professors other than your instructor** for help with a project, they:

Essentially did the project for you.

Completed most of the project for you.

Told/showed you what to do, but you had to complete the project on your own.

Told/showed you only some of what you would need to do, and you had to make it work yourselves.

Did not help you figure out what you needed to do.

Not applicable.

4. When you encountered **problems with your design**, your instructor:

Fixed it for you.

Told you exactly what you needed to do to fix it.

Provided suggestions/advice, but you had to choose a course of action and fix the problems.

Listened to you describe the problems, but did not provide advice.

Was not aware of or involved in problem-solving.

Not applicable.

5. 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?

*Essentially the instructor.*  
He/she told you exactly what you needed to do to accomplish the tasks.

*Mostly the instructor.*  
He/she told you most of what you needed to do, and you didn't have to figure out very many things on your own.

*You and the instructor share responsibility.*  
He/she gave you advice on how to accomplish tasks, and then helped you figure out how to implement the strategies you chose.

*Mostly you.*  
You were not automatically given advice or direction about most of the tasks, but received suggestions/advice when you asked for it.

*Essentially you.*  
You set your own direction and did not receive advice when you asked for it.

6. 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?

*Essentially the instructor.*

*Mostly the instructor.*

*You and the instructor share responsibility.*

*Mostly you.*

*Essentially you.*

7. When you feel **anxious about your performance** in this course, you are most often concerned about whether:

Your performance will earn the course grade you desire.

You are learning things directly related to your future career.

Your performance will please the instructor.

Your performance will please your teammates.

Your design will meet the needs of your client.

8. Which of the following most accurately describes the **learning environment** in your design course?

The instructor completely controlled what and how we learned.

The instructor defined broad goals or tasks, and we were expected to achieve them.

We defined and were expected to achieve broad goals or tasks, with the instructor's guidance.

We completely controlled what and how we learned.

For each statement below, please choose the one option that best characterizes your level of agreement with the statement.

	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree Nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
9. Our design was <b>student-directed</b> and a result of our team's decision-making rather than the work of our instructor.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. The <b>handiwork and craftsmanship</b> involved in our design is a result of our team's work, rather than being completed by technicians or professors.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. Taking this course is helping me <b>make the transition</b> from being a student to being a professional.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. As this course/series of courses progressed, we received less assistance and direction from instructors and <b>took on more responsibility</b> for our decisions and actions.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. In this course, I was allowed to <b>make mistakes and then learn from the consequences</b> of those mistakes.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. This is a course where " <b>you get out of it what you put into it</b> " - if you take it seriously and put effort into the class, you'll learn a lot; if you treat the class like a game or a joke, you won't learn much.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. If asked, you could clearly <b>explain why design courses are a defining element</b> of an engineering education.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I'm <b>proud</b> of what I have achieved in this class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

For each activity listed below, please choose the one option that best characterizes how often you performed the activity.

<i>As this course/series of courses progressed, I had to:</i>	<b><i>Almost Never</i></b>	<b><i>Not Very Often</i></b>	<b><i>Often</i></b>	<b><i>Very Often</i></b>	<b><i>Almost Every Day</i></b>
17. separate personal issues from professional responsibilities when working in a team.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
18. manage competing demands for resources and time.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19. objectively evaluate the work of my peers.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20. objectively evaluate my own performance.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21. teach myself things in order to accomplish our tasks.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22. take responsibility for getting something finished.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23. make choices or decisions even though I didn't know everything there possibly was to know about an issue.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24. solve unexpected problems.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25. accommodate other people's schedules and needs instead of expecting them to accommodate mine.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>