

EFFECTS OF FACULTY INTERACTION AND FEEDBACK ON GAINS IN STUDENT SKILLS

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Abstract – Researchers have identified a number of variables including the nature and frequency of instructor-student interaction affect students' gains in learning outcomes and course satisfaction. This study specifically examined the relationships between engineering faculty teaching practices and classroom climate and students' gains in communication skills, problem-solving skills, occupational awareness, and engineering competence in a curriculum emphasizing engineering design activities. The study was based on data gathered from more than 1500 students taking the first-year design course offered at 19 campuses of the Penn State University system over a period of two years. The results suggest that faculty interacting with and providing constructive feedback to students was significantly and positively related to student gains in several engineering design and professional skills. These relationships remained after controlling for student demographic characteristics and campus location. The focus of this paper is to provide engineering instructors with insights about the relationships between faculty-student interaction and selected student gains. Recommendations regarding specific teaching practices are provided.

INTRODUCTION

In the last decade, the National Science Foundation and engineering colleges have placed greater emphasis on integrating engineering design into the curriculum, emphasizing hands-on projects, teamwork, and greater student-student and student-faculty collaboration. At the first-year level these efforts were targeted to interest students in engineering as a profession and subsequently retain the students in their majors.

Penn State's College of Engineering developed the Introduction to Engineering Design (ED&G 100) course as a part of a National Science Foundation sponsored coalition project, Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL). ECSEL was a coalition of engineering colleges of seven universities, funded between 1990 and 2000, and focused on the goals of increasing the recruitment and retention of underrepresented students in engineering and infusing design throughout the four-year curriculum. ED&G 100, a required course for engineering majors, is offered at 19 Penn State campus locations and promotes a design-driven curriculum with emphasis placed on skills such as: teamwork,

communication skills (graphical, verbal, and written), and computer-aided analysis tools. The curriculum introduces students to the engineering approach to problem solving, emphasizing the use of basic science and math skills to test and evaluate design ideas by building working prototypes. The design projects require students to work in teams, and their course grades reflect their ability to function effectively as team members. These enhancements were intended to increase student confidence and increase the value of the course within the curriculum. Beyond simply providing students with the opportunity to work with peers on particular assignments, however, what do instructors intend to be the educational benefits for college undergraduate engineering majors participating in team design projects?

Generally, curricula incorporating collaborative learning aim to develop students' problem-solving skills, their abilities to apply theories to "real-world" problems, and their functioning as effective team members [1]. In working in teams to solve ill-structured design problems and construct working prototypes, engineering students also cultivate their communication and conflict management skills [2]. A meta-analysis of the effects of small-group learning on undergraduates in engineering, science, technology, and math indicates that working in small groups promotes academic achievement and college persistence [3]. Likewise, a recent study of 718 students found that active learning experiences (e.g., team design projects) had positive direct and indirect effects on college student persistence [4].

While the body of research on the relationships between collaborative learning techniques, student achievement, persistence, and affective outcomes is growing, few studies have investigated engineering faculty's role in fostering student gains through students' participation in design projects that foster teamwork. Previous studies have found that student-faculty interaction promotes educational attainment, and is significantly and positively related to college grade point average, degree attainment, graduating with honors, and enrollment in graduate school [5]. Since engineering faculty are proactively experimenting with educational activities in the classroom, "the impact of faculty upon student involvement and persistence is likely to arise indirectly via their impact on ethos and educational activity structure of the classroom.... It can therefore be argued that at least part of the often-observed relationship between persistence and student-faculty contact outside the classroom is a reflection of faculty actions" [6, p. 90]. A

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number of studies have found that student-faculty interaction both in and outside the classroom is critical to a number of the aforementioned outcomes [5, 6, 8]. However, this study specifically examines *engineering* faculty-student interaction occurring in the context of design-driven curricula in the first-year.

Previous research also indicates that active, collaborative learning and faculty-student interaction promote academic achievement and college persistence. Few studies, however, have investigated the relationships between faculty interaction and students' self-perceptions of outcomes other than academic achievement and persistence [7]. The purpose of this study was 1) to investigate the effects of certain instructional practices or activities on students' self-perceptions of gains made in problem-solving skills, awareness of what practicing engineers do, confidence in becoming engineers, and communication skills and 2) to determine the extent to which classroom climate affects these student outcomes.

DATA SOURCE

The Introduction to Engineering Design course (ED&G 100) is offered at 19 campuses of the Penn State system with a total enrollment of 1800 students per year. Approximately, 50 percent of the students attend the University Park campus, and the rest are distributed among 18 campuses statewide. Approximately, 25 faculty teach the course across the various campuses in any one year. Although the course content is the same at all campuses, the design projects vary from campus to campus. ED&G 100 is a three-credit course that involves six hours of in-class work (two hours per session, three times a week).

TABLE I
DEMOGRAPHICS OF THE DATA SAMPLE

Item		n	%
Gender	Female	289	18.6
	Male	1266	81.4
Race/Ethnicity	African American/Black	51	3.3
	Latino/Hispanic	38	2.5
	Asian/Pacific Islander	83	5.4
	American Indian/Native	10	.7
	Alaskan	1321	85.9
	White/Caucasian	34	2.2
Class Year	First Year	1220	79.1
	Sophomore	220	14.3
	Junior	72	4.7
	Senior	21	1.4
	Other	10	.6

N = 1555

Characteristics of the Sample

One thousand five hundred fifty-five (1,555) students participated in the study by completing a questionnaire at the end of the fall 1999, spring 2000, or fall 2000 semesters. Eight hundred eight University Park students and 747 students from 18 other Penn State campus locations participated in the study. The respondents' mean SAT Verbal score was 576; the mean Math score was 634. Information was collected about students' residence, parents' education level, the highest degree students' expected to earn, race/ethnicity, gender, and class year. See Table I for more information about the demographics of the sample.

THE STUDY

This study was conducted using Classroom Activities and Outcomes questionnaire developed by the Penn State's Center for the Study of Higher Education (CSHE). This instrument was developed as part of the assessment of curricular innovations of the ECSEL project. The questionnaire was used to investigate students' experiences in a particular engineering course, how much the course affected their engineering-related skills, and background and demographic characteristics [9]. Terenzini et. al. [10] and Colbeck et. al. [7] describe in detail the theoretical underpinnings of the Classroom Activities and Outcomes questionnaire. This paper, therefore, provides only a brief description of the variables included in this study.

Instructional Activities and Classroom Climate

Students responded to 26 items that asked about the kinds of instructional activities used in and the characteristics of the ED&G 100 course by circling the number on a four-point scale that best reflected their perceptions. The scale included "1 = never," "2 = occasionally," "3 = often," "4 = very often/almost always."

A principal components factor analysis with varimax rotation generated four constructs: Instructor Interaction and Feedback, Collaborative Learning Activities, Instructor Climate, and Peer Climate (see Table II). Factor analysis is a statistical technique used to summarize large amounts of data and identify relationships among multiple variables. Rotation is used to rotate the axes of a scatterplot to maximize the variance between the factors (i.e., to maximize the difference between factors). This four-factor model accounted for 54.4% of the item variation (adjusted $R^2 = 54.4$). That is, Instructional Activities and Classroom Climate accounted for over half of the reason students made gains in the design and professional skills examined in this study. The internal consistency reliability was high for all four factors, with Cronbach's alphas between .80 and .90.

TABLE II
FACTOR LOADINGS FOR INSTRUCTIONAL ACTIVITIES AND CLASSROOM CLIMATE

Item	Instructor Interaction & Feedback	Collaborative Learning	Instructor Climate	Peer Climate
Instructor Interaction and Feedback	.759			
The instructor makes clear what is expected of students, activities, and effort.	.751			
The instructor gives me detailed feedback.	.732			
The instructor gives me frequent feedback.	.685			
Assignments and activities are clearly explained.	.660			
I interact with the instructor as part of this course.	.639			
The instructor guides students' learning activities, rather than lecturing or demonstrating.	.597			
Assignments, presentations, and activities are clearly related.	.586			
The instructor encourages students to listen, to evaluate, and to learn from others' ideas.	.546			
I have opportunities to practice skills.	.541			
I am encouraged to challenge instructor's and students' ideas.	.539			
The instructor emphasizes the design process and activities.	.438			
I interact with the instructor outside of class.				
Collaborative Learning				
I discuss ideas with classmates.		.768		
I get feedback from classmates.		.686		
There are opportunities to work in groups.		.684		
Students teach and learn from one another.		.633		
I work cooperatively with other students.		.632		
We do things that require students to be active participants.		.567		
I interact with other students in this course outside of class.		.411		
Instructor Climate				
The instructor treats minority students in the same way as white students.			.859	
The instructor treats women students in the same way as male students.			.829	
Peer Climate				
Some white students treat minority students differently from other white students.				.876
When working in groups, some male students treat women students differently from other male students.				.875
Some male students treat women students differently from other male students.				.873
When working in groups, some white students treat minority students differently from other white students.				.837
Internal consistency reliability (alpha)	.88	.80	.80	.90
% of Variance Explained	54.44			

Cronbach's alpha is a measure of strength where 1.0 suggests a perfect correlation.

of the correlation matrix. Therefore, the skills named above constituted almost 62% of the skills students gained.

The Skills Students Gained

A principal components factor analysis with varimax rotation of 27 outcome items produced four factors: Group Communication Skills, Problem-Solving Skills, Occupational Awareness, and Engineering Competence (see Table III). Again, internal consistency reliability of the factors was quite high (Cronbach's alphas between .80 and .93). The adjusted R² accounted for 61.5% of the variance

METHODS

Multiple regression analyses were run to identify the significant predictors of students' perceptions of the progress they made in Problem Solving Skills, Occupational Awareness, Group Communication Skills, and Engineering Competence. Listwise selection of variables was used to eliminate any variables with missing values. Eliminating the

TABLE III
FACTOR LOADINGS FOR LEARNING OUTCOME VARIABLES

<i>Item</i>	<i>Group Skills</i>	<i>Problem Solving Skills</i>	<i>Occupational Awareness</i>	<i>Engineering Competence</i>
GROUP SKILLS				
Pay attention to all group members' feelings.	.793			
Listen to the ideas of others with an open mind,	.782			
Works on collaborative projects as a member of a team.	.724			
Develop ways to resolve conflict and reach agreement in a group.	.673			
Problem Solving Skills				
Identify the tasks needed to solve an unstructured problem.		.732		
Develop several methods that might be used to solve an unstructured problem.		.722		
Divide problems into manageable components.		.702		
Clearly describe a problem in writing..		.690		
Identify the knowledge, resources, and people needed to solve an unstructured problem.		.685		
Evaluate arguments and evidence so that strengths and weaknesses of competing alternatives can be judged.		.677		
Clearly describe a problem orally.		.673		
Solve an unstructured problem.		.669		
Apply an abstract concept or idea to a real problem.		.660		
Weigh the pros and cons of possible solutions to a problem.		.650		
Visualize what the product of a design project would look like.		.567		
Figure out what changes are needed in prototypes so that the final engineering project meets design specifications.		.488		
Occupational Awareness				
Knowledge and understanding of the process of design.			.693	
Knowledge and understanding of the language of design.			.669	
Understanding of what engineers do in industry or as faculty.			.655	
Understanding of the non-technical dimensions of engineering.			.582	
Engineering Competence				
Likelihood that you will continue in engineering.				.868
Likelihood that you will become a practicing engineer.				.855
Confidence that majoring in engineering was the right choice.				.833
Likelihood that you will go on to graduate school in engineering.				.830
Motivation to become an engineer.				.839
Confidence in your ability to become an engineer.				.760
Likelihood that you will pursue a teaching career in engineering.				.591
Internal consistency reliability (alpha)	.87	.93	.80	.92
% of Variance Explained	61.49			

non-significant variables until only significant items remained produced the four reduced models.

RESULTS

Table IV identifies the significant variables in predicting the four outcome variables, and their beta weights. Beta weights help assess the relative importance of the independent variables relative to the given model of a regression equation. A finding is considered statistically significant if the chance of obtaining the outcome by chance only is very low (e.g., less than five times out of 100). Peer climate and

instructor climate were not significantly related to students' perceptions of their learning gains.

Expected grade ($p < .05$), participation in collaborative learning activities ($p < .001$), and instructor interaction and feedback ($p < .001$) were significantly and positively related to students' self-reported gains in problem solving skills. Year in school was significantly and negatively related to gains in problem solving abilities ($p < .05$). This finding suggests the further along in their collegiate careers, the less likely students were to believe the ED&G 100 course boosted their problem solving skills. Consequently, first-year students reported higher gains in problem solving skills

TABLE IV
BETAS FOR THE REDUCED MODELS, CONTROLLING FOR ALL OTHER
INDEPENDENT VARIABLES

	Learning Outcomes			
	Group Skills	Problem Solving Skills	Occupational Awareness	Engineering Competence
Gender				.069 *
SAT Math	-.081 *			
SAT Verbal	-.067 *			-.124 **
Year in School	-.066 *	-.061 *	-.060 *	
Expected Grade		.067 *		.207 **
Collaborative Learning	.276 **	.149 **	.099 **	
Instructor Interaction and Feedback	.279 **	.481 **	.497 **	.373 **
Peer Climate	-.053 *		-.047 **	
R ²	.259 **	.356 **	.319 **	.226 **

* $p < .05$, ** $p < .001$

than did more advanced students as a result of taking ED&G 100.

Collaborative learning and instructor interaction and feedback were significantly ($p < .001$) and positively related to students' perceptions of gains in occupational awareness. Like with problem solving skills, year in school was significantly ($p < .05$) and negatively related to occupational awareness.

Participation in collaborative learning activities and instructor interaction and feedback were significant predictors ($p < .001$) of students' developing group communication skills. This finding makes sense since group projects require students to interact with each other and with the instructor, thereby increasing the chances that students will develop more advanced communication skills. SAT math and verbal scores and year in school ($p < .05$) were negatively associated with students' self-perceived gains in communication skills.

Four variables were associated with students' development of Engineering Competence. Gender was positively related to Engineering Competence at the .05 significance level, suggesting men had more confidence than did women that engineering was the right major for them and that they will continue in engineering. SAT verbal score was negatively associated with this learning outcome ($p < .001$). Expected grade and instructor interaction and feedback were significantly and positively related to self-reported student gains in Engineering Competence at the .001 level of significance. Students who expected higher grades were more confident than their peers with lower grades in their motivation to and confidence in becoming engineers.

Instructor Interaction and Feedback was the only variable significantly associated with each of the four learning outcomes. Furthermore, the magnitude of the instructor interaction variables' beta weights indicates that

instructor interaction and feedback was the strongest contributor to the model for these learning outcomes. Figure 1 shows that students reported the greatest gains in all four learning outcomes when they interacted with and received feedback from the instructor "almost always."

IMPLICATIONS FOR TEACHING

Since instructor interaction and feedback was the greatest contributor to all of the learning outcomes of this study, this section focuses on instructors' roles in student learning, and offers some recommendations for improving the ways in which faculty interact with and offer feedback to their students.

Instructor-student interaction can take on many forms and many degrees of intensity. For instance, faculty may interact with students both in and out of the classroom, discuss course-related topics, and offer academic advice. Out of class conversations on substantive matter, and faculty-supervised internships or research opportunities provide excellent opportunities to interact with students [12].

The nature of design courses allow situations where faculty can interact more often with students than they do in lecture-driven courses and, therefore, have a greater affect on students' learning gains. Specific features of ED&G 100 that may have contributed to the findings of this study include:

- Design projects by nature require significant amount of class time to problem solve. Providing in-class time to engage in design activities provides more opportunities for faculty-student interaction.
- The ED&G 100 class meets six hours per week, which increases the opportunity for faculty-student interaction.
- Small class size (maximum 32 per section), and students working in team of four (eight teams per section).
- Design projects have multiple deliverables including giving weekly presentations, writing reports, and building and testing prototypes. These activities require students to work closely with their team members with constant guidance from faculty.

Instructors of design-driven courses like ED&G 100 have the opportunity to not only interact with students more often, but to provide valuable feedback in a timely manner as well. Vines and Rowland [13] applied the concept of feedback mechanisms in electrical engineering applications to create their Instructional Feedback model, which suggests that faculty implement many "sensors" (e.g., homework, group projects, exams) to gauge students' progress through any one course. The authors' model compares instructors to "actuators" that provide correction to the system (i.e. student progress) by providing frequent and detailed feedback. They also suggest faculty apprise students of their progress or shortcomings several times during a course, in order to give students the opportunity to change their approach or study habits to learn more successfully.

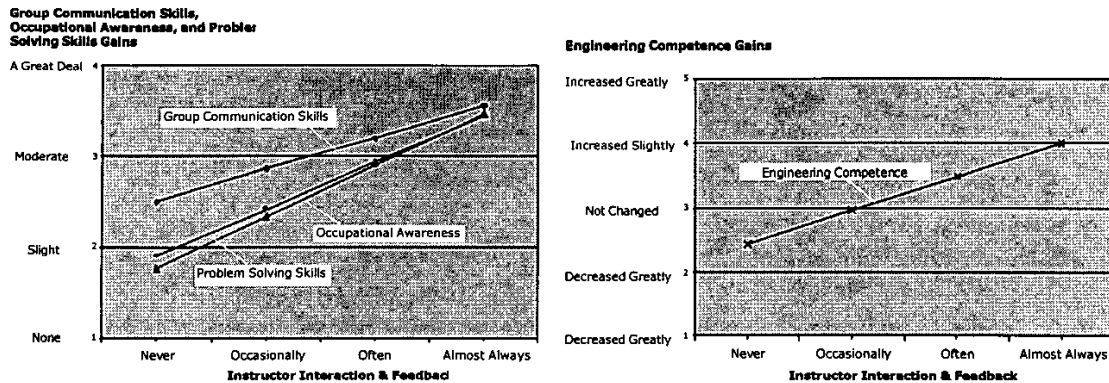


FIGURE 1
PREDICTED MEAN SCORES FOR LEARNING OUTCOMES BY INSTRUCTOR INTERACTION AND FEEDBACK

In regard to whether instructors ought to give feedback immediately or after a period of time, the findings of recent study indicate “immediate feedback intervention is more effective when automatic processing occurs while delayed feedback produces greater change with tasks involving deliberative and effortful processing” [11, p. 365]. Therefore, instructors are advised to provide immediate feedback for modifying psychomotor skills and to wait to give feedback (until the next class period, for example) to instill changes in students’ long-term memory. In all cases, instructors ought to re-examine a student’s learning or skills development after the student has had an opportunity to make adjustments based on faculty feedback.

While instructors may know the processes by which interaction can occur, respectful and open attitudes pave the way for greater student involvement. Ways to foster student-instructor interaction include transmitting, by verbal or non-verbal communication, an attitude that values students’ opinions and contributions. For example, faculty might solicit student views in class, and be willing to discuss divergent points of view that may arise. Success in creating an environment conducive to faculty-student interaction depends largely on the personality of the instructor and to what extent the students think the instructor is accessible [12, 14].

CONCLUSIONS

Discussions of course enhancement regularly include only changes to the course content, which is often the case when adapting a lecture-based course curriculum to a design- or project-based curriculum. The success of any new course is frequently measured by the impact the course content on student grades. By integrating design projects and collaborative learning opportunities in the classroom, faculty are far more likely than their lecturing peers to engage with students and their learning. In turn, greater faculty-student involvement, in addition to its contribution to student

retention and academic success, also promotes student gains in engineering design and professional skills.

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