MORE THAN MEETS THE EYE: CURRICULAR AND PROGRAMMATIC EFFECTS ON STUDENT LEARNING

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Abstract

This paper reports the effects of program characteristics and faculty activities on students' experiences and, ultimately, the development of students' analytical and group skills. Data come from nationally representative samples of 4,330 seniors, 1,243 faculty members, and 147 engineering program chairs on 39 campuses nationwide. Findings indicate that program characteristics and faculty behaviors and values have significant, if relatively small and largely indirect, effects on student learning by encouraging (or discouraging) certain kinds of student experiences, which, in turn, influence student learning. The results point to a need for more complex designs than are typically adopted in most learning outcomes studies.

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Background and Purpose

After reviewing 30 years of research, Pascarella and Terenzini (1991, 2005) concluded that "the evidence strongly suggests that . . . *multiple forces* operate in *multiple settings* to influence student learning and change" (2005, p. 629). Their review indicated, however, that most studies of the effects of college on students adopt an overly narrow conceptual focus, concentrating on only a comparative handful of factors at a time. The result is a body of evidence that, with few exceptions (e.g., Astin, 1993), "present[s] only a partial picture of the forces at work" (2005, p. 630).

Much of the research on college effects on students has focused primarily on some subset of students' college experiences. These studies typically concentrate on the influences of the curriculum (e.g., the majors they choose and the courses they take), or the classroom (e.g., the kinds of pedagogies their instructors adopt), or students' out-of-class experiences (e.g., where they live, co-curricular involvement, interactions with peers and faculty members, employment, family responsibilities). Relatively few studies, however, have examined the effects of students' experiences in each of these venues comprehensively, assessing the effects of students' experiences in each venue while controlling for their experiences in the others. The National Study of Student Learning (see Pascarella et al., 1996; Springer, Terenzini, Pascarella, & Nora, 1995; Terenzini, Springer, Pascarella, & Nora, 1995) and the National Survey of Student Engagement (Kuh, 2001), two of the largest studies of college impacts undertaken in the past 15 years rest on such a conceptual foundation and are noteworthy exceptions to the more restricted conceptual vision underlying most other studies.

Both the evidence and logic, however, suggest that factors in *addition* to students' college experiences may influence their learning in ways not yet identified or fully understood. A body of research considerably smaller than that concerned with the "student experience" has examined institutional characteristics as explanatory factors. These "between-college effects" studies explore the extent to which student outcomes are attributable, net of other factors, to differences in the characteristics of the institutions students attend. Most of these studies rely primarily on structural features, such as type of control, curricular mission, size, and selectivity. Such measures, however, are consistently poor predictors of virtually *any* student outcome once entering students' precollege characteristics are taken into account (see, for example, Astin, 1993; Dey, et al., 1997; Pascarella & Terenzini, 1991, 2005). Occupational and economic outcomes are the sole exceptions to this generalization. Pascarella and Terenzini (1991, 2005) suggest that the conventional institutional descriptors are too remote from the student experience to have much impact and are, consequently, largely unrelated to gains in student learning.

In efforts to move beyond an institution's structural features as influences on student learning, some studies have examined college and universities' *internal* organizational features as possible influences on student outcomes. For example, some scholars have explored differences in the allocation of financial resources as a possible source of institutional impacts on learning, or the effects of an institution's financial context on degree completion (Titus, 2006). These studies suggest that institutional expenditure patterns can shape student experiences and outcomes, although the magnitude of the effects tend to be small (Belfield & Thomas, 2000; Ryan, 2004; Smart, Ethington, Riggs, & Thompson, 2002; Toutkoushian & Smart, 2001). Porter (2006) also identifies institutional structures (such as peer ability, institutional density, differentiation in the curriculum, and an institution's research orientation) that affect student engagement.

Another (also relatively small) body of research identifies features of an institution's operational functioning, climate, or culture that can be clustered to characterize internal organizational environments. Berger and Milem (2000), for example, identify five such environments: bureaucratic, collegial, political, symbolic, and systemic. These "organizational effects" studies suggest that organizational environments and cultures may be more influential forces than the more commonly used structural characteristics (e.g., Astin & Scherrei, 1980; Berger, 2000; 2001-2002, 2002; Braxton & Brier, 1989; Smart & Hamm, 1993; Berger & Milem, 2000 provide a thorough review of this literature). These environmental clusters are useful in explaining student outcomes, but they are relatively abstract, describing an organization's general operational behaviors and tendencies to make decisions in a particular fashion. They resemble the conventional structural descriptors in their level of aggregation and generality and, consequently, are still relatively distal from students' experiences and, for practical or policy purposes, resistant to intervention or change.

It seems reasonable to suggest that other institutional features, such as peer environments, faculty cultures, and *internal*, structural, programmatic, and policy considerations are more proximal to students' experiences and outcomes than factors considered to-date and may also play a role. These frequently overlooked factors may shape students' experiences in subtle, if indirect ways, but their subtlety or indirectness should not be taken to mean they are inconsequential influences on student learning and development. Recent research suggests that the certain organizational contexts and internal features may influence student outcomes, but those influences are more likely to be indirect than direct, being mediated through the nature of the peer environment and the kinds of student experiences they encourage or discourage (Lattuca, Terenzini, & Volkwein, 2005; Reason, Terenzini, & Domingo, 2005, 2006).

In the mid-1990s, the Accreditation Board of Engineering Education (ABET) adopted criteria for evaluating engineering programs nationwide that were dramatically different from the previous criteria (Engineering Accreditation Commission, 1998). The new model, known as "EC2000" (shorthand for the title of the document specifying the new criteria), shifted the emphasis of the program accreditation review away from the possession of specific resources and facilities to 11 specific learning outcomes, such as " design[ing] a system, component, or process to meet desired needs" and "function[ing] on multidisciplinary teams." In 2002, ABET commissioned a study of the effectiveness of EC2000 in increasing the level of engineering graduates' preparation to enter the profession. The database developed for that assessment offered an exceptional opportunity to examine the proposition that what institutions *do* programmatically – their academic programs, practices, and policies, as well as the faculty culture, have a measurable, if indirect, effect on student learning. The study reported here undertook a comprehensive evaluation of the effects of internal organizational features, such as shifts in program curricula and characteristics, and changes in faculty members' practices and values, on students' learning-related experiences and, in turn, the development of their analytical and group skills. Although the subjects of this research were engineering students, programs, and faculty members, the findings (because of the relatively generic nature of the outcomes studied) have implications for enhancing learning in other professional and academic fields.

METHODS

Conceptual Framework

Figure 1 portrays the hypothesized quasi-causal sequence initiated by the introduction of the new EC2000 accreditation standards. The framework suggests that, if the new criteria are having an impact on undergraduate engineering education, those effects will be apparent first in changes in the curriculum and instructional practices engineering programs offer as faculty members move to align their curricula and instructional practices in ways likely to promote the learning outcomes specified in EC2000. One might also expect to see shifts in the faculty culture toward greater involvement in learner-centered activities such as outcomes assessment and professional development activities that might improve a faculty member's teaching. One might anticipate changes in administrative policies and practices, such as increased emphasis on teaching and learning when making hiring, promotion, and tenure decisions. To the extent that these curricular, instructional, cultural, and organizational shifts are occurring, one might then expect the degree of those shifts to be reflected in differences in the nature and extent of the experiences students report. The framework, finally, suggests that differences in student experiences will be reflected in differences in student learning.

-- Insert Figure 1 About Here --

This study evaluates the overall conceptual framework, ascertaining the extent to which effects of changes in program characteristics and faculty activities are reflected in differences in students' experiences and, ultimately, in the development of their analytical and group-functioning skills. This set of propositions suggests that students' development of these skills is a function not only of what occurs in the classroom and the kinds of out-of-class, engineering-related experiences students have during their undergraduate programs, but also of the organizational components relating to program characteristics and faculty behaviors and values that shape those experiences.

Design, Population, and Sample

The analyses reported here are part of a large, three-and-one-half-year national study of the effects of the introduction of ABET's new accreditation criteria on the preparation of undergraduate engineers to enter their profession. Because of time and resource constraints, the research group adopted a pre-/post-test, cross-sectional, *ex post facto* design that included graduates of the engineering classes of 1994 and 2004. Because the present study is concerned only with the effects of programmatic and cultural changes on student experiences and learning, the analyses here are based on data gathered in 2004.

The population for the present study includes all 2004 graduates of ABET-accredited undergraduate engineering programs offering at least two of seven engineering disciplines: aerospace, chemical, civil, computer, electrical, industrial, and mechanical. This disciplinary array includes both those disciplines that produce the vast majority of engineering graduates in any given year (chemical, civil, electrical, and mechanical), as well as disciplines with strong ties to industry sectors (aerospace, computer, and industrial).

The overall project dataset was developed using a two-stage, 7x3x2, disproportional, stratified random sample. Of the population of 1,241 ABET-accredited engineering programs in the targeted disciplines, 1,024 met the accredited-since-1990 specification. In the first stage, 40 of those institutions were randomly selected within three strata: 1) the targeted seven disciplines, 2) three categories in the EC2000 review cycle (i.e., programs that chose to be reviewed under EC2000 before being required to do so, to be reviewed when it was mandatory, or elected to defer EC2000 review when that option was available), and 3) whether the school's programs had participated in a National Science Foundation Engineering Education Coalition during the 1990s (these coalitions were among the leaders in moving to meet the EC2000 criteria). To ensure an adequate number of responses for analysis within each discipline, selection was "disproportional" in over-sampling institutions with programs in the smaller disciplines (aerospace and industrial). To ensure representative samples of graduates and faculty members, four EC2000 pilot institutions (first reviewed in 1996 and 1997) were also included, as were several Historically Black Colleges and Universities (HBCUs) and Hispanic Serving Institutions (HSIs). The final sample included 147 programs at 39 institutions.

Data Collection Procedures

The overall project's design entailed data collection from several sources, including graduating seniors in 2004, engineering graduates from the same programs in 1994, faculty members, program chairs, deans, and employers (data from deans, employers and the 1994 graduates were not used in the study reported here). In the fall of 2003, survey instruments were sent to 2,971 faculty members and 203 program chairs. In spring, 2004, the population of 12,621 seniors nearing graduation in any of the seven engineering fields on the each of the 40 campuses were sent the final survey instrument (all instruments are available at http://www.ed.psu.edu/cshe/abet/instruments.html). One institution did not provide student responses, reducing the institutional sample to 39. The Graduating Senior Survey solicited information on basic demographic information, level of participation in out-of-class activities related to engineering education, student-learning outcomes associated with each of the 11 EC2000 outcomes criteria, classroom practices, and plans for the future. Before data collection began, the dean of the college of engineering on each campus sent e-mail requests soliciting student and faculty participation. Follow-up waves included a postcard reminder sent two weeks after the initial mailing, and a complete follow-up (similar to the initial mailing) sent two weeks after the postcard.

Responses were received from 4,543 graduating seniors (a 36% response rate), 1,272 faculty members, and the chairs of 147 engineering programs on 39 campuses. Any student or faculty case with more than 20 percent of the possible responses missing was deleted from the database, yielding 4,330 usable student cases (a usable response rate of 34%), 1,243 faculty members (a 42% response rate), and 147 (72% response) of the program chairs. Missing data in the usable student and faculty cases were imputed using expected maximization procedures (Allison, 2001).

Graduating seniors described their undergraduate engineering experiences (both inside and outside the classroom) and reported their skill levels in engineering design and analysis and in working in groups. Program chairs reported on a wide array of program characteristics and curricular changes made since implementation of the EC2000 reaccreditation criteria. Faculty members reported on a broad array changes made in their instructional approaches and other professional practices and development activities over the past decade.

Variables

The criterion measures came from 36 items produced in a lengthy, detailed process to operationalize the 11 learning outcomes criteria specified in EC2000 (see Strauss & Terenzini, 2005). Respondents were asked to indicate their level of achievement on each of these skill items using a 5-point scale, where 1 = “No Ability” and 5 = “High Ability.” A series of principal component analyses produced nine scales, two of which are the dependent variables in this study. Table 1 summarizes the composition of these two scales and their internal consistency (Cronbach’s alpha) reliabilities. The final, nine-factor solution retained 75.3 percent of the overall item variance among the original 36 survey items, all of which loaded above .40 on a single factor; none loaded above .45 on any two factors (the full factor structure and scale reliabilities are given in Strauss & Terenzini, 2005). Factor scale scores were calculated by summing students' responses to each item loading above .45 on a component and dividing by the number of items in the scale (Armor, 1974). Two of the nine factors, one dealing with students' group skills, the other with their design and analytical skills were selected for this study. Scale alphas for these two scales are: Design and Analytical Skills = .92 and Group Skills = .86. These two scales were chosen for this study because each represents one of the two major categories frequently used to classify engineering skills: professional skills (such as communication skills, interpersonal skills) and technical skills (such as problem-solving, technological skills, and design skills). The Design and Analytical Skills scale taps students' abilities to solve unstructured engineering problems (i.e., those for which there is no single or "correct" solution). The Group Skills scale reflects students' abilities to work successfully with others to accomplish a team goal.

-- Insert Table 1 About Here --

The independent variables fall into five sets: 1) students' precollege characteristics (e.g., sociodemographic traits and academic preparation), 2) institutional characteristics and students' discipline, 3) six scales measuring engineering program characteristics (e.g., curricular emphases); 4) nine scales tapping faculty members' instructional practices and attitudes, as well as the faculty culture, and 5) ten items reflecting students' in- and out-of-class activities relevant to engineering education. With three exceptions, the alpha reliabilities for all student, program, and faculty scales exceed .70.

Because the study was concerned with identifying the effects of changes in program curricula and pedagogies, the faculty culture, and program policies on students' experiences and subsequent learning, potentially confounding precollege student characteristics were controlled, as were institutional characteristics and graduates' engineering discipline. Individual differences used as covariates included students' age, gender, high school preparation in basic math and science. Institutional characteristics include such differences as type of control, Carnegie classification, institutional size and wealth. The operational characteristics of these and all other variables are listed in Table 2.

-- Insert Table 2 About Here --

Three scales represent students' in-class experiences. The instructional practices set of variables included three, factorially derived (principal components with varimax rotation) scales: Clarity and Organization, Collaborative Learning, and Instructor Interaction and Feedback. Each scale was formed by summing its component items (loadings above .40) and dividing by the number of items in the scale. These scales consist of three, seven, and five items respectively, with alphas of .82, .90, and .87. Two scales were also created to represent the students' perception of program openness to ideas and people. This scale consists of four indicators and has alphas of .74. There were also six out-of-class experiences measured through student responses. The first was program diversity climate which was a scale created from four indicators with an alpha of .57. The final five out-of-class experiences were conceptualized through single observed student responses (e.g., cooperative education experiences, study abroad, and internship/coop participation). The component items for each of these scales are given in Table 2.

Changes in the curriculum, pedagogies used, faculty culture, and program practices and policies are measured by nine faculty activities scales and six program scales. Changes in the program's curriculum and organizational practices and policies were measured using six factorially derived (principal components with Varimax rotation) scales (created using procedures identical to those adopted to create the criterion measures). These scales tapped changes in the program's curricular emphasis on content focusing on foundational engineering skills, contexts and standards for engineering, communication skills, and project-related skills. Two scales measured shifts in resources and in a program's emphasis on teaching for hiring, promotion, and tenure decisions.

Nine scales measured changes in faculty members' instructional practices and attitudes. These indicators tapped increases in faculty members' engagement in professional development and outcomes assessment projects to improve the education they and their programs offer, increased emphasis in their courses on engineering contexts (e.g., social, environmental, economic) and on ethics and professional standards, increased emphasis on key engineering project skills (e.g., communication and group skills), and any shifts in their courses' emphasis on foundational engineering knowledge and applied skills. Two factors assessed faculty shifts in the learning pedagogies they employed. As with all other variables, the operational forms of these measures are given in Table 2.

For analytical purposes, all faculty variables were converted to "composite" variables by averaging individual faculty members' responses or scale scores within each program within each institution. These composite scores were then matched to individual students in the same engineering program at the same institution. Program variables derived from program chairs were similarly matched to individual students within the chairs' programs.

Analytical Procedures

Data were analyzed using hierarchical (or blocked) ordinary least-squares (OLS), multiple regression. Analyses proceeded in two phases. In Phase 1, each of the 10 student in- and out-of-class experience variables was regressed on students' precollege characteristics (the control variables) and then on the program and faculty composite variables. In Phase 2, each of the two outcome scales was regressed on all control variables, all program and faculty composite variables, and all student experience variables. The beta weights (and changes in them as the analyses proceeded) provided information on direct and/or indirect effects of programmatic and faculty influences on students experiences and, ultimately, learning outcomes.

In Phase 2, two regression models were run for each dependent variable. In both models, students' precollege characteristics were entered as the first block. In the first regression, the program change and faculty activities variables were entered ahead of students' in- and out-of-class experiences. In the second regression, the order was reversed, with the program- and faculty-change variables block entered after students' in- and out-of-class experiences. This procedure was intended to allow estimation of the two unique-variance terms attributable to program and student-experience variable sets, as well as the joint contributions of the two sets. The joint contribution, in essence, is the residual variance explained after subtracting from the overall R^2 the variance due to students' precollege characteristics and to the unique variance terms contributed by the program and student-experience variable sets.

FINDINGS

Analyses indicate that program curricula and structures and faculty practices and values shape students' development of both their analytical and group skills. The programmatic and faculty influences, however, are largely indirect rather than direct, affecting student learning by encouraging (or discouraging) certain kinds of student experiences, which, in turn, directly shape each student learning outcome.

As can be seen in Table 3, and with Design and Analytic Skills as the criterion variable, the total variance explained by the model containing control variables, program changes, faculty activities, and student experiences is 23.2 percent. With Group Skills as the dependent variable, the model accounts for 18.1 percent of the total variance. For both outcome measures, however, the contributions of program-related changes are vastly smaller than those attributable to students' experiences. The program changes and faculty activities uniquely explain less than one percent of the total variance. The joint variance explained by the two sets of variables is also very low. These findings indicate that the direct effects of program changes and faculty activities on either student learning outcome are not very powerful, although the fact that they explain *any* unique variance at all suggests the possibility that they may have indirect effects and, thus, are at least of theoretical interest.

-- Insert Table 3 About Here --

Effects of Program Changes on Student Experiences. Evidence of broad (if modest) influence of program variables on students' experiences, however, is apparent in Table 4 and consistent with theoretical expectations. All six of the program-related scales had a statistically significant influence (with $p < .05$ or lower) on at least one student experience, and three scales (increased emphasis on teaching in faculty personnel decisions, and increased curricular emphasis on communication skills and on project skills) had statistically significant effects ($p < .05$ or lower) on more than one student-experience. With the alpha significance criterion relaxed to $p < .10$ (not an unreasonable step, given the attenuated power of composite predictor variables and the interest in this study on testing a relatively new substantive proposition), five of the six program variables predicted differences in two or more student experiences, and three program variables (changes in resources and increased emphasis on communication skills and on project skills) had an influence on three or more student experiences. Changes (mostly increases) in programmatic emphasis on communication skills and project skills appeared particularly influential. All of these influences are apparent even after taking into account students' precollege characteristics and selected traits of the institutions they attend. For six of the ten student experiences, the faculty and program factors explained 10 percent or more of the variation in the student experiences, and two more approach that mark.

-- Insert Table 4 About Here --

Effects of Faculty Changes on Student Experiences. The lower half of Table 4 summarizes the evidence relating to faculty influences on students' experiences. The findings shown there also suggest the possible presence of indirect effects and are consistent with the theoretical expectations implied in Figure 1. All but one of the nine faculty variables have a statistically significant influence on at least one student experience (faculty involvement in innovations intended to improve engineering education is the sole exception). Four of the nine faculty activity shifts had a net effect on two student experiences, and one (an increased emphasis in class on project skills) had a significant and positive influence on four student experiences. Under the more forgiving $p < .10$ criterion, all nine faculty scales have an impact on at least one student experience, and four have an influence on three or more experiences. Several of these effects are rather robust, such as the positive influence of faculty members' increased use of active learning pedagogies and increased course emphasis on foundational engineering content on students' involvement in internships and cooperative education experiences, as well as the strong negative effect on that same experience of faculty emphasis on applied skills. Some of these significant effects (by whatever standard) are negative and not easily interpretable, but the pattern clearly indicates a role for factors reflecting faculty practices and the faculty culture in the kinds of experiences graduates report.

Effects of Student Experiences on Learning Outcomes. As can be seen in Table 5, and as one might expect, the measures of students' in- and out-of-class experiences were by far the strongest predictors of the students' group and design and analytical skills. Looking first at the Group Skills model, seven of the ten student experiences are significant, even after controlling for precollege student characteristics and institutional traits. Exposure to active and collaborative pedagogies had a positive, and the largest, effect on the level of students' group skills. Students' perceptions of their program's openness to new ideas and people, and of their campus' diversity climate, also had a noteworthy effect on the level of group skills the students developed.

-- Insert Table 5 About Here --

Eight of the ten in- and out-of-class experiences were significant predictors of students' Design and Analytical Skills. Their instructors' clarity in the classroom and interactions with, and feedback to, students had the largest effects on students' design and problem-solving skills.

Effects of Program, Faculty, and Student Experiences on Learning. Table 6 summarizes the direct effects (beta weights) of all independent variables on students' group and analytical skills after controlling for students' precollege characteristics and institutional traits. Program characteristics and faculty activities account for only a small portion of the total variation in the outcome variables, but several scales reflecting changes faculty members reported making in their courses show statistically significant *direct* effects on the student outcome variables net of other factors. In programs where faculty members increased their emphasis in their courses on foundational engineering knowledge (basic science, basic engineering science, and foundational math) and reported less emphasis on traditional pedagogies, students reported higher levels of learning on both outcomes than did their peers in programs with faculty members who devoted less course attention to foundational engineering content. Faculty perceptions that teaching was recognized favorably in the faculty hiring and reward system, however, appeared to affect those skills negatively, if only marginally.

Students in programs where faculty members engaged in professional development activities to improve themselves as educators reported higher design and analytical skills than their counterparts in programs where faculty members were less engaged in teaching-related professional development activities. Only one program-related characteristic – increased emphasis on students' communication skills – had a significant effect on a learning outcome, and its effects on student design and analytical skills was negative. No explanation for this finding is immediately apparent.

-- Insert Table 6 About Here --

With the inclusion of program changes and faculty activity into the model, the student experience beta weights for all but one factor change at least somewhat. The most substantial change is the disappearance of students' perceptions of their program's diversity climate. The effects of participation in a student chapter of a professional society or association also disappears when predicting the Group Skills measure, and its statistical significance drops sharply when predicting students' Design and Analytical Skills. Participation in engineering design competitions also loses power in influencing students' group skills. Three other student experiences decline in influence with the addition of the program change and faculty activity factors. These drops in the effect sizes of student experiences when program and faculty factors are taken into account constitutes additional evidence of the presence of indirect effects relating to program changes and faculty activities on learning outcomes through their influence on students' experiences. These analyses would suggest that programmatic and faculty choices can have both direct and indirect effects on student learning outcomes.

Limitations

This study, like any other, is limited in several ways. First, the dependent constructs – group skills and design and analytical abilities – are complex skill sets and not easily measured. Although the process used to create these scales closely followed the canons of survey instrument development (Strauss & Terenzini, 2005), the resulting measures may only partially reflect the range of talents needed to be proficient in these skill areas. Direct observations of these skills would be preferred but also difficult to obtain from the more than 4,000 students on 39 campuses across the country who participated in the study.

Second, only graduating seniors in engineering participated in the study. Although respondents were representative of the national population of undergraduate engineering graduates, generalization of study results to students in other academic areas (even in other science, technology, engineering, and math disciplines) is probably limited by the specialized and technical nature of engineering as a field of study.

Third, the study relies on self-reports of student learning, and one must acknowledge the possible weaknesses of such data. A growing body of empirical evidence, however, suggests that, under certain conditions (believed to exist in this study's outcome measures), self-reported learning can be a reasonable proxy for other, more objective measures (Anaya, 1999; Bradburn & Sudman, 1988; Carini, O'Day, & Kuh, 2002; Converse & Presser, 1989; Hayek, Laing, Sawyer, & Noble, 1988; Pace, 1985; Pike, 1995). Moreover, although self-reports have acknowledged limitations when compared with standardized tests, the latter come with their own limitations, including availability, length, cost, administration requirements, and relevance to the outcomes of interest.

Fourth, the evidence relating to the indirect effects of program characteristics and faculty behaviors and attitudes on student learning was not fully tested. Because of the complexity of the conceptual framework and number of predictor variables, no structural equation models were attempted. The findings reported here, however, suggest there may be information to gain from such analyses.

CONCLUSIONS AND IMPLICATIONS

This study examined the proposition that *internal* organizational structures, practices, and policies – what institutions *do* – affects learning. Assuming that multiple factors contribute to what and how students learn, we explored how changes in curricula, instruction, administrative policies and procedures, and faculty culture shaped students' undergraduate educational experiences, and how, in turn, these changes influenced learning outcomes. The findings highlight the complexity of the processes at work and the importance of adopting comprehensive models to guide research on college students develop and change: Learning in engineering programs (and probably most other professional and academic fields) appears to be influenced not only by students' experiences during college, but also by programmatic changes and faculty activities that encourage some kinds of experiences and discourage others.

For two key engineering outcomes – group skills and design and analytical skills – what program faculty do and what they value makes a difference in student learning. Increased emphasis on course topics associated with the learning outcomes specified in the EC2000 accreditation criteria, greater use of active learning and decreased use of traditional pedagogies, greater faculty participation in professional development activities, and greater emphasis on teaching in the faculty reward system are consistently related to greater student involvement in learning-related experiences inside and outside the classroom. All but two of the faculty and program variables studied shaped at least one student experience, and a few influenced several. The effects of an emphasis on active learning techniques and foundational topics in math, science and engineering topics are fairly robust. The remaining effects tend to be small, although their small size may be attributable, at least in part, to the aggregation of data to the faculty average within programs and use of program-level data, with the consequent attenuation of variance in those predictors. The reported relations are, thus, conservative estimates of the unique contribution of the variables and the existence of any measurable effect is, as a result, worth noting.

The study findings also indicate that students' classroom experiences are significant, if modest, predictors of the two criterion measures. Collaborative experiences in the classroom, as well students' perceptions that their academic program promotes diversity, tolerance, and respect for differences, contribute to the development of students' group skills. Students' in- and out-of-class experiences also moderately influence development of their design and analytical skills. Clarity of instruction, collaborative work in courses, and the amount of interaction with, and feedback from, faculty play a part in students' development of skills in engineering design and analysis.

Although less influential, out-of-class experiences such as internships, participation in design competitions, and involvement in student chapters of professional engineering organizations similarly make significant contributions to the outcomes under study. In addition, students' perceptions of their programs' openness to diverse ideas and people contribute to the development of both group and design/analytical skills. The items in the program openness scale assess the degree to which students perceive their courses and program address and value an understanding of diversity. The more programs work to create a climate conducive to difference and discussions of difference, the more students develop skills that are essential to their success in the engineering profession.

When all the variables are included in the regression models, all but one of the program scales drop out, but a number of faculty variables remain. Faculty members' emphasis on foundational knowledge and decreased use of traditional pedagogies *still* have measurable, direct effects on the development of students' group skills. In addition, faculty members' participation in professional development activities focused on teaching and assessment, as well the emphasis they place in their courses on foundational knowledge, have direct effects on design and analytical skills. While student experiences are the largest and most consistent predictors of learning outcomes in the regression models, the persistence of these faculty-related direct effects strongly suggest that many factors in addition to students' experiences promote learning in engineering programs. Moreover, the consistent pattern of indirect effects of program and faculty variables on learning via their influence on student experiences should alert researchers to be wary of the *post hoc* fallacy, that is, the assumption that because one event immediately precedes another, the first event causes or is the only influence on the subsequent variable. The evidence of indirect effects is a reminder not to overlook other, more remote and subtle, factors that *also* contribute to particular outcomes. These analyses show that many of the decisions that faculty make affect students' educational experiences, which then in turn affect learning.

In the quasi-causal sequence explored in this study, the pattern of direct and indirect relationships, and the particular factors that lead to the relationships between student experiences and learning outcomes, have implications for theory development, policy, and practice. Simplistic models of student learning imply that researchers can identify, and administrators and policy makers can adopt, silver bullets or best practices which will substantially improve student learning. More than two decades of research demonstrate that the equation is much more complex; many different factors affect student learning and development (Pascarella & Terenzini, 2005). Ignoring the indirect effects of programmatic factors presents an incomplete picture of the forces that shape student learning, reducing attention on what affects learning to a few variables that represent only a fraction of a student's educational experience. Furthermore, the tendency to focus only on direct effects tends to obscure the role that program features and faculty activities such as curriculum revision and professional development play in promoting learning. In these analyses, faculty decisions about curricula and participation in professional development had significant direct effects on learning, but many additional program and faculty decisions *also* influenced the student experience inside and outside the classroom. Furthermore, institutional policies that fail to reward faculty for their efforts to enhance their pedagogical knowledge and program curricula ultimately shortchange students. Finally, the national policy conversation about student learning in higher education suffers when researchers and policy makers discount comprehensive research designs and reform efforts that acknowledge the contribution made by the many different links that constitute the chain of influences on student learning. The search for the silver bullet narrows, rather than expands, thinking and action. As long as such constricted views dominate academic and policy decision-making, educational reform and innovation will amount to tinkering at the margins, and the impacts likely to be predictably small.

References

Allison, P. D. (2001). *Missing data*. Sage University Papers Series on Quantitative Applications in the Social Sciences, No. 07-136. Thousand Oaks, CA: Sage.

Astin, A. (1993). *What matters in college?* Four Critical Years *revisited*. San Francisco: Jossey-Bass.

Astin, A., & Scherrei, R. (1980). *Maximizing leadership effectiveness*. San Francisco: Jossey-Bass.

Belfield, C. R., & Thomas, H. R. (2000). The relationship between resources and performance in further education colleges. *Oxford Review of Education, 26*, 239-253.

Berger, J. B. (2000). Organizational behavior at colleges and student outcomes: A new perspective on college impact. *Review of Higher Education, 23*, 177-198.

Berger, J. B. (2001-2002). Understanding the organizational nature of student persistence: Empirically-based recommendations for practice. *Journal of College Student Retention, 3*, 3-21.

Berger, J. (2002). The influence of the organizational structures of colleges and universities on college student learning. *Peabody Journal of Education, 77*, 40-59.

Berger, J., & Milem, J. (2000). Organizational behavior in higher education and student outcomes. In J. C. Smart (Ed.), *Higher Education: Handbook of Theory and Research* (Vol. XV, pp. 268-338). New York: Agathon.

Braxton, J., & Brier, E. (1989). Melding organizational and interactional theories of student attrition: A path analytic study. *Review of Higher Education, 13*, 47-61.

Dey, E., Hurtado, S., Rhee, B., Inkelas, K. K., Wimsatt, L. A., & Guan, F. (1997). *Improving research on postsecondary outcomes: A review of the strengths and limitations of national data sources*. Palo Alto, CA: Stanford University, National Center for Postsecondary Improvement.

Engineering Accreditation Commission. (1998). Engineering Criteria 2000: Criteria for Accrediting Programs in Engineering in the United States (2nd ed.). Baltimore, MD: Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, Inc.

Kuh, G. (2001, May/June). Assessing what really matters to student learning: Inside the National Survey of Student Engagement. *Change, 33,* 10-17, 66.

Kuh, G. D., Hu, S., & Vesper, N. (2002). "They shall be known by what they do": An activities bases typology of college students. Journal of College Student Development, 41(2), 228-245.

Lattuca, L. R., Terenzini, P. T., & Volkwein, J. F. (2005, October). Findings from *Engineering change: A study of the impact of EC2000.* Presentation to the annual meeting of the Accrediting Board for Engineering and Technology, San Diego, CA.

Pascarella, E. T., & Terenzini, P. T. (1991). How college affects students: Findings and insights from twenty years of research. San Francisco: Jossey-Bass.

Pascarella, E. T., & Terenzini, P. T. (2005). How college affects students(Vol. 2): A third decade of research. San Francisco: Jossey-Bass.

Pascarella, E., Whitt, E., Nora, A., Edison, M., Hagedorn, L., & Terenzini, P. (1996). What have we learned from the first year of the national study of student learning? *Journal of College Student Development, 37,* 182-192.

Porter, S. R. (2006). Institutional structures and student engagement. *Research in Higher Education, 47,* 521-558.

Reason, R. D., Terenzini, P. T., & Domingo, R. J. (2005, November). Developing social and personal competence in the first year of college. Paper presented at the meeting of the Association for the Study of Higher Education, Philadelphia, PA.

Reason, R. D., Terenzini, P. T., & Domingo, R. J. (2006). First things first: Developing academic competence in the first year of college. *Research in Higher Education, 47*(2), 149-175.

Ryan, J. F. (2004). The relationship between institutional expenditures and degree attainment at baccalaureate colleges. *Research in Higher Education, 45*(2), 97-114.

Smart, J., Ethington, C., Riggs, R., & Thompson, M. (2002. Influences of institutional expenditure patterns on the development of students' leadership competencies. *Research in Higher Education, 43*(1), 115-132.

Smart, J., & Hamm, R. (1993). Organizational culture and effectiveness in two-year colleges. *Research in Higher Education, 34,* 95-106.

Springer, L., Terenzini, P., Pascarella, E., & Nora, A. (1995a). Influences on college students' orientations toward learning for self-understanding. *Journal of College Student Development, 36*, 5-18.

Strauss, L. C., & Terenzini, P. T. (2005). Assessing student performance on EC2000 Criterion 3.a-k. Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, Portland, OR. June 11-14.

Terenzini, P., Springer, L., Pascarella, E., & Nora, A. (1995). Academic and out-of-class influences affecting the development of students' intellectual orientations. *Review of Higher Education, 19*, 23-44.

Titus, M. A. (2006). Understanding college degree completion of students with low socioeconomic status: The influence of the institutional financial context. *Research in Higher Education*, *47*, 371-398.

Toutkoushian, R., & Smart, J. (2001). Do institutional characteristics affect gains from college? *The Review of Higher Education, 25*(1), 39-61.

Figure 1: Conceptual Framework for the Engineering Change Study

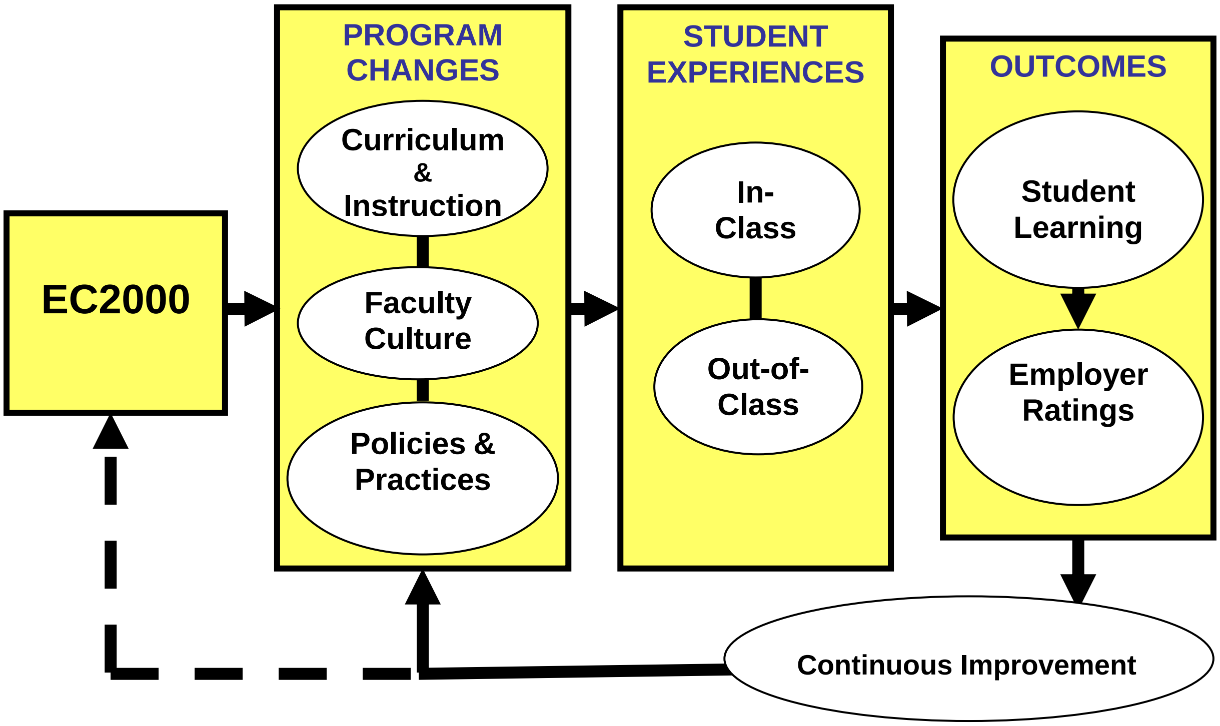

Table 1. Factor structure underlying items operationalizing two EC2000 learning outcomes criteria.

Scale Label and Highest Loading Items	Number of Items	Factor Loadings	Scale Alpha	Percent of Total Variance Explained
Design and Analytical Skills	6		.92	12.4%
Design solutions to meet desired needs		.78		
Apply systematic design procedures to open-ended problems		.77		
Define key engineering problems		.76		
Formulate a range of solutions to an engineering problem		.75		
Understand essential aspects of the engineering design process		.66		
Apply discipline-specific engineering knowledge		.47		
Group Skills	3		.86	7.1
Work with others to accomplish team goals		.86		
Work in teams of people with a variety of skills and backgrounds		.84		
Work in teams where knowledge and ideas from multiple engineering disciplines must be applied		.67		
TOTAL VARIANCE EXPLAINED BY 9-FACTOR SOLUTION				75.3%

Table 2. Independent variables used in OLS regression analyses.

Control Variables

1. Students' Precollege Characteristics

Age: Actual years

Sex: 1 = male, 0 = female

Transfer status: 1 = native freshman on entry, 0 = transfer

Citizenship: 1 = U.S. citizen, 0 = not a U.S. citizen

Race/Ethnicity: Black/African American, Hispanic or Latino, Asian, American Indian/Alaskan Native, Hawaiian or Pacific Islander, and other, each coded as a dummy variable (1 or 0) with white used as the comparison group

Family income: 9-point scale, where 1 = below $20,000 and 9 = more than $150,000

Highest level of education attained by mother: 4-point scale, where 1 = high school diploma, GED, or less and 4 = advanced degree

Highest level of education attained by father: 4-point scale, where 1 = high school diploma, GED, or less and 4 = advanced degree

SAT scores: Actual scores on both the math and verbal sections of the SATs

Overall high school GPA: 6-point scale, where 1 = below 1.49 (below C-) and 6 = 3.5 to 4.0 (A to A-)

Preparation for basic science and math courses when entering college: An Individual's response to the question: How well prepared were you for basic science and math courses when you entered college? On a 4-point scale, where 1 = not at all and 4 = very well prepared

2. Institutional Characteristics

Type of control: 1 = public, 0 = private

NSF coalition participation: 1 = member of coalition, 0 = not a coalition member

EC2000 review schedule: early (1998-2000) and on-time (2001-2003) – each coded as a dummy variable (1 or 0) with late (2004-2006) used as the comparison group

Carnegie classification: Carnegie Research Extensive, Carnegie Research Intensive, and Carnegie Masters – each coded into dummy variables (1 or 0) with Carnegie Bachelors as the comparison group

Wealth: Average salary of full professors in engineering, converted to z-scores

Size: Number of undergraduate engineering degrees awarded in 2004, converted to z-scores

Engineering discipline: Industrial, Mechanical, Aerospace, Chemical, Civil, and Computer – each coded as dummy variables (1 or 0) with Electrical used as the comparison group

Independent Variables

3. Program Changes

Emphasis on Teaching in Faculty Personnel Decisions: The program chair's individual score on a 3-item scale (where 5 = significant increase, and 1 = significant decrease) that assesses the change in the emphasis on teaching in personnel matters. Constituent items: "Recruiting and hiring;" "Promotion and tenure;" and "Salary and merit increases." (Alpha = .89)

Change in Resources: The program chair's individual score on an 8-item scale (where 5 = significant increase and 1 = significant decrease) that assesses the approximate change in program resources over the past 10 years. Constituent items: "Instructional staff;" "Support staff;" "Instructional resources;" "Institutional funds for innovations;" "Faculty professional development;" "Research resources;" "Facilities;" "Financial resources." (Alpha = .87)

Emphasis on Foundational Knowledge: The program chair's individual score on a 5-item scale (5 = significant increase, to 1 = significant decrease) that assesses the approximate change in the program's emphasis on the following areas over the past decade. Constituent items: "Basic engineering science;" "Foundational math;" "Basic science;" "Experimental methods;" "Engineering problem solving." (Alpha = .74)

Contexts and Standards: The program chair's individual score on a 5-item scale (5 = significant increase, to 1 = significant decrease) that assesses the approximate change in the program's emphasis on the following areas over the past decade. Constituent items: "Professional ethics;" "Engineering in global/social contexts;" "Professional responsibility;" "Life-long learning;" "Knowledge of contemporary issues." (Alpha = .79)

Communication Skills: The program chair's individual score on a 3-item scale (where 5 = significant increase, to 1 = significant decrease) that assesses the approximate change in the program's emphasis on the following areas over the past decade. Constituent items: "Verbal communication;" "Technical writing;" "Interpersonal/group communication." (Alpha = .79)

Project Skills: The program chair's individual score on a 4-item scale (where 5 = significant increase, to 1 = significant decrease) that assesses the approximate change in the program's emphasis on the following areas over the past decade. Constituent items: "Engineering design;" "Use of modern engineering tools;" "Project management;" "Teamwork." (Alpha = .72)

4. Instructional Practices and Attitudes of Faculty Members

Personal Improvement: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 4-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the faculty member's participation compared to five years ago. Constituent items: "Seminars or workshops on assessing students learning;" "Seminars or workshops on teaching and learning;" "Using services of on-campus instructional center;" "Reading materials on teaching." (Alpha = .73)

Projects to improve engineering education: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 5-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the faculty member's participation compared to five years ago. Constituent items: "A project to improve undergraduate engineering education;" "Applying for external funding for an undergraduate engineering education project;" "Developing or teaching a course with someone in another engineering discipline;" "Conference or journal submission on undergraduate education;" "Activities to enhance content knowledge." (Alpha = .64)

Contexts and Standards: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 4-item scale (5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Professional ethics;" "Engineering in global/social contexts;" "Professional responsibility;" "Knowledge of contemporary issues." (Alpha = .78)

Emphasis on Foundational Knowledge: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 3-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Basic science;" "Basic engineering science;" "Foundational math." (Alpha = .84)

Project Skills: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 4-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Verbal communication;" "Technical writing;" "Teamwork;" "Project management." (Alpha = .74)

Applied Skills: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 3-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Modern engineering tools;" "Experimental methods;" "Engineering design." (Alpha = .51)

Active Learning Pedagogies: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 7-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Design projects;" "Assignments or exercises focusing on application;" "Open-ended problems;" "Student presentations;" "Use of groups in class;" "Hands-on experiences;" "Case studies or real-world examples." (Alpha = .78)

Traditional Pedagogies Scale: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 2-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Lectures;" "Problems form the textbook." (Alpha = .48)

Emphasis on Teaching in Faculty Personnel Decisions: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 3-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Recruiting and hiring;" "Promotion and tenure;" "Salary and merit increases." (Alpha = .90)

5. Student reports of their in-class and out-of-class activities relevant to engineering

Clarity and Organization Scale: An individual student's score on a 3-item scale (where 4 = almost always, to 1 = almost never) assessing how often things happened in their classes. Constituent items: "Assignments and class activities were clearly explained;" "Assignments, presentations, and learning activities were clearly related to one another;" "Instructors made clear what was expected of students in the way of activities and effort." (Alpha = .82)

Collaborative Learning Scale: An individual student's score on a 7-item scale (where 4 = almost always, to 1 = almost never) assessing how often things happened in their classes. Constituent items: "I worked cooperatively with other students on course assignments;" "Students taught and learned from each other;" "We worked in groups;" "I discussed ideas with my classmates (individuals or groups);" "I got feedback on my work or ideas from my classmates;" "I interacted with other students in the course outside of class;" "We did things that required students to be active participants in the teaching and learning process." (Alpha = .90)

Instructor Interaction and Feedback Scale: An individual student's score on a 5-item scale (where 4 = almost always, to 1 = almost never) assessing how often things happened in their classes. Constituent items: "Instructors gave me frequent feedback on my work;" "Instructors gave me detailed feedback on my work;" "Instructors guided students' learning activities rather than lecturing or demonstrating the course material;" "I interacted with instructors as part of the course;" "I interacted with instructors outside of class (including office hours, advising, socializing, etc.)." (Alpha = .87)

Program Encouragement for Openness: An individual student's score on a 4-item scale (where 4 = almost always, to 1 = almost never) assessing how often things happened in the program both in-class and out-of-class. Constituent items: "My engineering courses encouraged me to examine my beliefs and values;" "My engineering courses emphasized tolerance and respect for differences;" "My department emphasizes the importance of diversity in the engineering workplace;" "My engineering friends and I discussed diversity issues." (Alpha = .74)

Perceived Program Climate: An individual student's score on a 4-item scale assessing how often things happened in the program when out-of-class. Constituent items: "In my major, I observed the use of offensive words, behaviors, or gestures directed at students because of their identity" (5 = strongly disagree, to 1 = strongly agree); "I was harassed or hassled by others in my major because of my identity" (5 = strongly disagree, to 1 = strongly agree); "I know some students who feel like they don't fit in this department because of their identity" (5 = strongly disagree, to 1 = strongly agree); "The faculty in my department are committed to treating all students fairly(5 = strongly agree, to 1 = strongly disagree)." (Alpha = .57)

Internship/Coop Experience: 5-point scale, measuring the months as an intern or cooperative education student, where 1 = none and 5 = more than 12 months

Study Abroad: 5-point scale, measuring the months in a study abroad program, where 1 = none and 5 = more than 12 months

International Travel: 5-point scale, measuring the months spent traveling internationally (not study abroad), where 1 = none and 5 = more than 12 months

Participation in Design Competition: 5-point scale, measuring the months spent in student design projects beyond classroom requirements, where 1 = none and 5 = more than 12 months

Involvement in Professional Society Chapter: 4-point scale, measuring the level of activity in a student chapter of a professional organization, where 1 = not at all and 4 = highly

Table 3. Partitioning of variance results for Design and Analytical Skills and Group Skills scales.

	Design & Analytical Skills	**Group Skills**
Variance due to precollege and institutional characteristics	.089***	.042***
Unique variance[a] due to:		
Program Changes and Faculty Activities	.008*	.008*
Student Experiences	.132***	.125***
Shared Variance	.003[b]	.006[b]
Total Variance Explained	.232***	.181***
Adjusted R^2	.216***	.164***

[a] Variance unattributable to any other variable set in the model.
[b] Cannot be tested for statistical significance.

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

Table 4. Effects[a] of program changes and faculty activities on students experiences.

	Clarity	Collaboration	Interaction	Program Openness	Climate	Internship/ Coop	Study Abroad	Travel	Design Competition	Prof Soc Chp
Program Scales										
Emphasis on Teaching in Faculty Personnel Decisions				-.050*					-.141***	
Change in Resources		.027+	.026+			-.051+	.023*			
Emphasis on Foundational Knowledge		-.079+			.078*					
Contexts and Standards		.086*								
Communication Skills				.092+				.088*	.205**	
Project Skills					-.047+	.150*	-.040+	-.122***		-.114+
Faculty Scales										
Personal Improvement										.518*
Projects to Improve Engineering Education								.189+		
Contexts and Standards	-.104+			-.126+	-.117*		-.105*			
Project Skills			.190**	.171*	.131*		.151**			
Emphasis on Foundational Knowledge						.346*				
Applied Skills			-.157*			-.705***				
Active Learning Pedagogies	.138*					.494**	-.098+		.250+	
Traditional Pedagogies						.263*			-.175+	
Emphasis on Teaching in Faculty Personnel Decisions	-.048+		-.078*		-.061*			-.038+		-.117+
R^2	.100	.123	.139	.111	.096	.106	.065	.147	.054	.089

+ p < .10, * p < .05, ** p < .01, *** p < .001

[a] Adjusted for student transfer status, age, gender, U S citizenship, race/ethnicity, mother's education, father's education, family income, test scores, high school GPA, discipline, and for institutional control (public/private), NSF coalition participation, EC2000 review schedule, Carnegie Classification, wealth, and size.

Table 5. Effects [a] of student experiences on Design and Analytical Skills and Group Skills scales.

Student Experiences	Group Skills	Design & Analytical Skills
In-Class		
Clarity	.066***	.149***
Collaboration	.275***	.059***
Instructor Interaction and Feedback		.136***
Program Openness	.101***	.089***
Out-of-Class		
Climate	.073***	.084***
Internship/Coop Experience	.026***	.029***
Study Abroad		
International Travel		
Participation in Design Competition	.045***	.082***
Involvement in Professional Society Chapter	.024**	.024**
R^2	.167	.224

+ p < .10, * p < .05, ** p < .01, *** p < .001

[a] Adjusted for student transfer status, age, gender, U S citizenship, race/ethnicity, mother's education, father's education, family income, test scores, high school GPA, discipline, and for institutional control (public/private), NSF coalition participation, EC2000 review schedule, Carnegie Classification, wealth, and size.

Table 6. Effects [a] of program changes and faculty activities and student experiences on Design and Analytical Skills and Group Skills scales.

	Group Skills	Design & Analytical Skills
Program Characteristics and Faculty Activities		
Program Scales		
Emphasis on Teaching in Faculty Personnel Decisions		
Change Resources		
Emphasis on Foundational Knowledge		
Contexts and Standards		
Communication Skills		-.107*
Project Skills		
Faculty Scales		
Personal Improvement		.196*
Projects to Improve Engineering Education		
Contexts and Standards		
Project Skills		
Emphasis on Foundational Knowledge	.242***	.159*
Applied Skills		
Active Learning Pedagogies		
Traditional Pedagogies	-.154**	
Emphasis on Teaching in Faculty Personnel Decisions	-.066*	
Student Experiences		
In-Class		
Clarity	.101***	.186***
Collaboration	.275***	.052**
Instructor Interaction and Feedback		.120***
Program Openness	.130***	.125***
Out-of-Class		
Climate		
Internship/Coop Experience	.031***	.032***
Study Abroad		
International Travel		
Participation in Design Competition	.036**	.089***
Involvement in Professional Society Chapter		.018+
R^2	.181	.232

+ p < .10, * p < .05, ** p < .01, *** p < .001

[a] Adjusted for student transfer status, age, gender, U S citizenship, race/ethnicity, mother's education, father's education, family income, test scores, high school GPA, discipline, and for institutional control (public/private), NSF coalition participation, EC2000 review schedule, Carnegie Classification, wealth, and size.