DEVELOPING PERFORMANCE INDICATORS FOR ASSESSING CLASSROOM TEACHING PRACTICES AND STUDENT LEARNING: The Case of Engineering

Alberto F. Cabrera, Carol L. Colbeck, Patrick T. Terenzini

Several states are requiring institutions to document changes in student outcomes. Regional and specialized accrediting agencies are also changing their review criteria from measuring inputs to assessing indicators of student learning. This article describes the results of an evaluation project that sought to develop performance indicators of learning gains for undergraduate engineering students. Specifically, the study investigated the relationship between classroom practices and students' gains in professional competencies. More than 1,250 students from 7 universities participated. Findings show that the instructional practices of Instructor Interaction and Feedback, Collaborative Learning, and Clarity and Organization are significantly and positively associated with gains in students' self-reported gains in problem-solving skills, group skills, and understanding of engineering as an occupation. The indicators meet several conditions recommended by the assessment literature. They are (1) meaningful to the user, (2) reliable and valid, and (3) index observable behaviors rather than subjective impressions.

KEY WORDS: student outcomes; classroom practices; assessment.

American higher education has been under intensive scrutiny for more than two decades from a variety of stakeholders seeking evidence of its effectiveness in achieving educational goals (Nedwek and Neal, 1994). Although consensus among legislators, employers, parents, media, and accreditation agencies as to what characterizes an effective institution of higher education is lacking, these stakeholders do concur in calling for indicators capturing the performance of the institution (Burke and Serban, 1998; Ewell, 1998). Accordingly, consider-

Alberto F. Cabrera is Associate Professor and Senior Research Associate, Carol L. Colbeck is Assistant Professor and Research Associate, and Patrick T. Terenzini is Professor and Senior Scientist, all at the Center for the Study of Higher Education (CSHE).

Address correspondence to: Alberto F. Cabrera, Associate Professor and Senior Research Associate, Center for the Study of Higher Education (CSHE), The Pennsylvania State University, 403 South Allen Street, Suite 104, University Park, PA 16801-5252; afc4@psu.edu.
able effort has been allocated to creating performance indicators that address the three major functions of a university: research, service, and teaching and learning. Of the three functions, the teaching and learning has received most attention (Burke and Serban, 1998; Whiteley, Porter, & Fenske, 1992).

Initial assessment efforts strove for universal performance indicators. These efforts rested on the notion that excellence could be appraised by assessing an institution’s reputation and resources. The popularity of reports from *Money Magazine*, *US News and World Report*, Barron’s *Profiles of American Colleges*, and *Peterson’s/AGB Survey of Strategic Indicators* illustrates the belief that reputational ratings capture the overall effectiveness of the institution. However, resource measures rest on the hope that they index the ability of the institution to deliver products and services. Accordingly, student demographics (e.g., gender, ethnicity, age), acceptance and matriculation ratios, average faculty salaries, number of library books and subscriptions to journals, proportion of faculty with PhDs, student credit hours per faculty member, degrees conferred, spending per student, and library holdings, to name a few, became the yardstick to measure institutional success.

The viability of resource and reputation indicators as proxies of institutional quality and predictors of college student learning began to be questioned in the early 1990s (Ewell, 1998). Pascarella and Terenzini’s (1991) review of 20 years of higher education research led them to conclude that conventional markers of institutional quality are poor predictors of student success. Once the characteristics of entering students were taken into account, the effects of institutional effectiveness measures disappeared. Recently, Hackett and Carrigan (1998) reached similar conclusions when they examined performance measures most commonly cited as valid indicators of financial stability. While internationally recognized as indicators of success, the aggregate measures of financial stability (e.g., expenditures per student, acceptance ratio, average faculty salary) were found to be poor predictors of an institution’s ability to maintain high enrollments or meet financial obligations. Hackett and Carrigan reported that institutional policy development was informed best when indicators of student success (e.g., retention) were employed instead of traditional measures.

Attention to outcomes and demonstrable results is playing an increasingly important role in public policy. Ewell (1998) estimates that two thirds of the states have developed assessment mandates compelling institutions of higher education to establish mechanisms for assessing and reporting student performance. Ewell’s observations regarding changes in the orientation of performance indicators in public policy seem to be confirmed by a recent study of the use of performance indicators in 11 states. Burke and Serban (1998) found that less than 15 percent of the 11 states they surveyed used resource or reputation indexes. Instead, most of the states surveyed had introduced indicators gauging impacts or results, particularly in the area of student development and gains in professional competencies, to guide public policy.

Emphasis on demonstrable changes in student outcomes is beginning to influence state funding practices as well. Some state initiatives like the 1998 Maryland’s Higher Education Reorganization Act seek institutional change by making public funding contingent on demonstrated ability to foster student learning and to retain students. The 1998 New York Plan (Performance Indicators Task Force, 1998) calls for the allocation of state funding ranging from 3 percent to 5 percent on the basis of four major groups of performance indicators: student achievement, faculty achievement, academic robustness, and quality of campus services. Although few states have adopted performance funding, Burke and Serban (1998) estimate that by the end of this century slightly more than 50 percent of the states will adopt funding schemes in which portions of state allocations to higher education institutions would be linked to demonstrated performance.

Interest in student development is also heightened by industrial leaders’ calls for college graduates who can work in teams and solve real world problems (Augustine, 1996; Black, 1994; Bucciarelli, 1988). In 1992, the National Educational Goals Panel, for instance, declared student developmental outcomes such as critical thinking, problem solving, effective communication, and responsible citizenship essential when judging the effectiveness of its institutional affiliates. Accrediting agencies have contributed to this trend by shifting their focus from global resource and reputational measures to indicators of teaching effectiveness. In 1996, for example, the Middle States Association of Colleges and Schools Agency placed teaching and learning as the centerpiece in institutional self-assessment. Recently, the North Central Accreditation Commission encouraged institutional evaluators to focus their attention on students’ gains in group interaction and problem-solving skills. Regional accreditation efforts are being matched by professional accrediting organizations. The Accreditation Board for Engineering and Technology (ABET), the sole agency responsible for accrediting engineering degrees in the United States, recently enacted criteria requiring colleges of engineering by the year 2001 to demonstrate their graduates have developed 11 competencies, including the abilities “to design systems or components, or process to meet desired needs,” “to function on multi-disciplinary teams,” and “to communicate effectively” (ABET, 1998).

This article describes the results of an evaluation project that sought to develop performance indicators of educational gains for undergraduate engineering students. The study also sought to document the connection between classroom practices and educational gains. The study is part of an ongoing evaluation of a major curricular reform undertaken by seven universities interested in incorporating design in undergraduate education and fostering diversity among engineering students. The universities are members of the National Science Foundation (NSF)-funded Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL), and include City College of New York, Howard University, Massachusetts Institute of Technology, Morgan State Uni-
PERFORMANCE INDICATORS FOR TEACHING AND LEARNING ENGINEERING

experiences as the center point where students’ academic and social experiences in college converge. Therefore, the Teaching for Professional Competence model focuses on classroom experiences and posits students’ pre-college characteristics, teaching practices, and classroom climate as predictors of gains in students’ professional competencies. The model also assumes both teaching practices and classroom climate have unique contributions on student development, reinforcing one another. A detailed review of the literature used in developing the Teaching for Competence model is presented in the following section.

Literature Review

Students’ Pre-College Characteristics: Ability and Background

Scholars who have investigated college impact have shown that student characteristics at time of matriculation influence the ways and extent to which students change as they progress toward graduation. Among factors known or presumed to affect students’ learning in college one can find: students’ intellectual ability, their educational aspirations, and the education level attained by their parents (Astin, 1993; Pascarella and Terenzini, 1991).

Students’ Pre-College Characteristics: Gender and Ethnicity

Research has shown that, under some conditions, gender and race influence what and how students learn (Oakes, 1990). Opinions differ, however, about the
reasons for gender- and race-related learning differences. The most compelling argument is based on differences in learning styles (Belenky, Clychly, Goldberg, and Tarule, 1986; Lundeberg and Diemert, 1995; Baxter-Magolda, 1992; Martínez-Alemán, 1997). According to this approach, women and minorities are more likely than white men to prefer collaborative learning settings because their learning styles emphasize connected knowing, cooperative problem solving, and socially based knowledge. In contrast, men (and some women educated in college by men) may be more likely than women to prefer traditional pedagogy given their more analytical, individualistic, and competitive learning styles (e.g., Belenky et al., 1986). Research evidence regarding gender- or race-based learning styles is mixed. Lundeberg and Diemert’s qualitative study of women attending a private, single-sex Midwestern college found women did prefer collaborative learning. Lundeberg and Diemert also observed that the collaborative nature of the student interactions promoted intellectual risk taking and connected understanding of concepts. However, Tinto (1997) found collaborative learning effective in promoting persistence in college, regardless of a student’s gender or race/ethnicity.

**Classroom Experiences**

Interest in classroom experiences has increased as research mounts regarding their connection with an array of student outcomes—including academic and cognitive development, knowledge acquisition, clarity in educational goals, interpersonal skills, and the quality of student effort spent in academic activities (e.g., Astin, 1993; Pascarella and Terenzini, 1991; Tinto, 1997; Volkwein, 1991; Volkwein and Lorang, 1996; Volkwein and Cabrera, 1998). This research also defines the classroom experiences as a complex phenomenon embracing teaching practices, the delivered curriculum as perceived by the students, and the climate permeating interactions among students and between the instructor and the students (Cabrera and Nora, 1994; Ewell, 1996; Stark & Lattuca, 1997). The classroom experience is so pivotal on student development that Tinto (1998) recently revisited his Model of Student Integration by placing the classroom experience as the center point whereby the academic and social experiences of the student with the institution converge.

In view of the importance of classroom experiences for student development, it is not surprising that attention has also been devoted to those forces shaping the classroom experience. Accordingly, curriculum—both formal and informal (Stark and Lattuca, 1997)—frequency and nature of interactions with faculty in the classroom (Pascarella and Terenzini, 1991), student learning styles (Belenky et al., 1986), gender and racial climate (Cabrera & Nora, 1994; Hurtado, 1992; Whitt, Pascarella, Edison, Nora, and Terenzini, 1998), and character of teaching practices (Murray, 1991) have received increasing recognition as important components of the classroom experiences.

**Classroom Experiences: Teaching Practices**

Research on the influence of instructional activities on student learning is somewhat mixed. Kulik and Kulik’s (1979) review of research on college teaching effectiveness led them to suggest learning had more to do with individual motivation to study outside the classroom than with what the instructor does in the classroom. Murray’s (1991) review of the limited research on low-inference teaching behaviors (e.g., what the instructor does in the classroom) led him to reach an opposite conclusion.

Research design and measurement issues may have prevented researchers from generating firm conclusions about the role of instructional activities (Abel, 1985; Murray, 1991). Murray found fewer measurement problems when the studies focused on concrete and observable “low-inference” teaching practices rather than when the studies relied on “high-inference” descriptors. “Student centered,” and “being friendly” are examples of high-inference measures that call for a high degree of inference and judgment on the part of the evaluator. A related low-inference teaching behavior is “the instructor encourages students to listen, to evaluate, and to learn from the ideas of other students.” In comparison to high-inference measures, low-inference behaviors are less prone to interpretation bias and more likely to be reported by more than one observer. In spite of the methodological superiority of low-inference over high-inference studies, Murray’s review of the literature found the high-inference approach dominating. Murray also found a major drawback of research on instructional activities: lack of studies examining the connection between student instructional ratings and gains in student learning and motivation.

Regardless of methodological problems, college teaching research has reached two major conclusions regarding classroom practices. They are multidimensional in nature, and their effectiveness across each dimension appears to vary as a function of the student outcome under consideration (McKeachie, 1988, 1990; Murray, 1991; Kulik and Kulik, 1979). Teacher clarity, for instance, has been found to correlate with student achievement (Feldman, 1989) and student motivation to re-enroll in courses (Murray, 1991). Continuous, specific, and immediate feedback has been found to improve mastery of foreign languages (Cardelle and Corno, 1981) and achievement (Kulik and Kulik, 1979). While both lecturing and class discussion correlate with acquisition of knowledge, class discussion appears to be more effective for enhancing problem-solving skills (Kulik and Kulik, 1979). In addition to class discussion, students’ critical thinking skills can be positively influenced by encouragement from teachers and a teacher’s articulation of problem-solving procedures (McKeachie, 1988, 1990).

Of the teaching practices, collaborative learning has been singled out as the most promising in bringing about student development (Garnson, 1994; Tinto, 1997, 1998). Collaborative learning involves collective intellectual effort among
groups of students. The practice of collaborative learning in the college classroom is grounded in the assumption that the processes of engaging in social conversation about a specific task or problem enhances participants’ reflective thinking and, therefore, their acquisition of knowledge (Bruffee, 1984). Collaborative learning, in all its manifestations (e.g., peer-learning, peer tutorial), has been found to positively correlate with problem solving, long-term retention of knowledge, achievement, application of concepts, sensitivity to fellow students’ feelings, positive attitudes toward subject area, student leadership behavior, student openness to diversity, and persistence (Cabrera, Nora, Bernal, Terenzini, and Pascarella, 1998; Johnson, Johnson, and Smith, 1991; Levine and Levine, 1991; McKeachie, 1990; Pascarella and Terenzini, 1991; Tinto, 1997).

In engineering education, collaborative learning has gained recognition as a promising method to develop relevant work-related competencies. Bucciarelli (1988) notes that in the workplace, engineers frequently work in groups or teams on design problems. Furthermore, he stresses that appropriate design processes only take place when team members can communicate effectively with one another. As such, students are more likely to develop work-related competencies when the classroom experiences mimic the work environment.

Research also indicates that instructional techniques need to reflect the content area to be effective. Emphasis on design and coaching has been stressed as a viable method in engineering education (McMartin, Van Duzer, and Agogino, 1998). While routine problem solving can be taught, according to Schon (1987), design cannot be taught using traditional lecture or discussion methods. Design is the art of developing creative solutions to open-ended problems and is a skill required in many professions (Schon, 1987). Students can learn design through practice as they are guided through frequent interactions with an experienced and encouraging coach (Dally and Zhang, 1993; Dym, 1994; Schon, 1987). Coaching involves interactive dialog, demonstrations, questioning, listening, clarifying objectives, understanding others’ viewpoints, and articulating design specifications (Dym, 1994, Schon, 1987).

Classroom Experiences: Classroom Climate

Although the nature of the classroom activity is in itself important for the attainment of student outcomes, the classroom climate of tolerance toward diversity also appears to play a role. A classroom climate permeated by prejudice and discrimination on the part of faculty and peers has emerged as an explanatory factor accounting for differences in college adjustment, majoring in hard sciences, and persisting in college between white men, women, and minority students (Cabrera and Nora, 1994; Cabrera, Nora, Terenzini, Pascarella, and Hagedorn, 1999; Drew, 1996; Eimers and Pike, 1997; Fleming, 1984; Whitt et al., 1998). Evidence suggests a strong association between negative collegiate experiences and women’s self-confidence in pursuing science, mathematics, and engineering majors (Drew, 1996; Sax, 1994). Women might be more likely to leave science and engineering majors than men because of their perceptions of competitiveness and inferior instruction in technical fields (Hall and Sandler, 1982; Strenta, Elliott, Adair, Matier, and Scott, 1994). Seymour and Hewitt (1997) found that women mentioned a hostile classroom climate in their engineering classes as a key factor in their decision to change majors. Thus, the climate of tolerance in a given class may also influence the extent to which students develop professional competencies as a result of taking that class.

Learning and Developmental Outcomes: Gains in Professional Competencies

Many academic and industry leaders, as well as accrediting agencies, agree that four years in college should develop students’ competencies in creative problem solving, communication, and group skills so they will be adequately prepared for the demands of the workplace (Ewell, 1998). Faculty members’, administrators’, and employers’ opinions about the essential skills college students should develop were explored in studies conducted by Jones and associates (1994, 1996; Jones et al., 1994; Jones, Dougherty, and Fantaske, 1997). Results of the Delphi studies revealed areas of consensus among the three groups of stakeholders about the components of critical thinking, problem solving, and communication skills (Jones et al, 1994, Jones et al., 1997).

Group Interpersonal Skills. Faculty, administrators, and employers agree that students should develop interpersonal and group skills, including identifying and adapting to the needs of others, motivating others, and managing interpersonal conflict (Jones, 1994). In the workplace, individuals frequently work in groups or teams to solve problems (Bucciarelli, 1988). Research on workplace groups reveals that three types of communication are involved in effective group functioning: discussions about the task, discussions about the process for achieving the task, and communications about personal relationships among group members (Jehn, 1997). Therefore, it is desirable that faculty foster classroom conditions enabling students to develop task, process, and relational communication skills among team members.

Problem-Solving Skills. Solving a problem involves several stages, including identifying the problem and generating, selecting, and implementing a solution (Dougherty and Fantaske, 1996). Problem solving often involves skills also associated with critical thinking, such as collecting and evaluating evidence, analyzing arguments, developing hypotheses, and drawing conclusions (Jones et al., 1994).

Design Skills. Design involves solving complex and ill-defined problems that may have many solutions (Schon, 1987). In addition to creativity, design usually includes generating and evaluating specifications to achieve objectives and satisfy constraints (Dym, 1994). Design problems are central to science and engi-
neering, architecture, art, music, business, and the health care professions (Dougherty and Fantaske, 1996; Schon, 1987). The new accreditation criteria for engineering colleges requires that graduates with a bachelor’s degree demonstrate competence in design (ABET, 1998).

While there may be consensus as to the competencies undergraduate students—particularly engineering students—should develop, there is less clarity about how to help students develop these competencies. Our review of the literature suggests that instructional practices should make a strong contribution to students’ gains in professional competencies. The purpose of this study was to investigate the relationship between instructional activities in engineering classrooms and students’ self-reported development of professional competencies.

DATA SOURCE AND METHODS

Subjects

In 1998, 1,258 students enrolled in engineering courses in ECSEL, an NSF-funded coalition of seven engineering schools, completed a pencil-and-paper, multiple choice questionnaire. The questionnaires were administered to 936 students in ECSEL classes and to 322 students in non-ECSEL classes. Instructional practices in the ECSEL classes were more likely to involve team-based and hands-on design projects. Non-ECSEL classes tended to stress traditional lecture and discussion techniques.

Questionnaire

The questionnaire was organized into four areas: (1) students’ background characteristics, (2) instructional practices in the particular course, (3) perceptions of classroom climate, and (4) the extent to which the students believed they gain in a variety of skill development as a result of taking the course. The items comprising each of the four sections of the questionnaire were derived from learning theory, research on college students, and from Delphi studies conducted by Jones (1994) and Jones and associates (1994).

Students’ Background Characteristics

Fifty-seven percent of the respondents were freshmen or juniors, and 43 percent were sophomores or seniors. Seventy-three percent of the respondents were male and 58.2 percent were White. The average respondent had college-educated parents, and expected to attain a master’s degree (see Table 1).

Classroom Experiences

This section of the questionnaire contained 26 items reflecting instructional practices and classroom climate issues. Students were asked to report how often they or the instructor engaged in each of the 20 instruction-related activities. They were also asked to report their experiences with six classroom climate related issues. The scale ranged from 1 to 4, where 1 = never, 2 = occasionally, 3 = often, and 4 = very often/always. The 20 instructional-related items were drawn from the research literature identifying effective instructional approaches and activities and designed to describe specific and observable teaching behaviors (Murray, 1991). The six classroom climate items were adapted from the perceptions of prejudice and discrimination scale (Cabrera and Nora, 1994) and designed to gauge students’ perceptions of a tolerant classroom climate toward women and minorities.

A factor analyses of the 26 classroom experiences items yielded a five-factor solution accounting for 62.2 percent of the variance in the correlation matrix. Three dimensions pertain to instructional activities. Two factors relate to perceptions of a tolerant classroom climate toward women and minorities.

Instructional Practices

The principal factor analysis identified three instructional practices factors. Collaborative Learning included seven practices that fostered interdependence among students working in groups. Instructor Interaction and Feedback included five instructional practices stressing frequent, detailed and supportive communication between faculty and students. Clarity and Organization included three practices involving clear explanations, expectations or integrated course structure (Appendix A lists items comprising each scale). The internal consistency of these scales was high, ranging from .77 to .88. (see Table 1).

Classroom Climate

Six items asked for students’ perceptions of a tolerant climate towards women and minorities. Two items asked whether students perceived that faculty treated women or minorities the same way as they treated male or white students. Four items asked students whether they perceived classmates treated women or minorities students differently from male or white students. Factor analyses results indicated these six items grouped into two distinct domains: Faculty Climate and Peer Climate (Appendix A lists items comprising each scale). These two scales are highly reliable (alphas = .86, 89).

Indicators of Learning Outcomes

Students were asked to report the progress they believe they made in 24 areas as a consequence of the course they were taking. Progress was reported on a 1 to 4 scale, where 1 = none, 2 = slight, 3 = moderate, and 4 = a great deal. The items were drawn primarily (but not exclusively) from a series of Delphi studies by Jones (1994) and her associates (Jones et al., 1994). Jones and her associates
sought to clarify and develop consensus among faculty members, administrators, researchers, and employers on definitions and components of critical thinking, problem solving, and communication skills. The items were also developed to reflect, as closely as possible, 7 of the 11 learning outcomes articulated in ABET's (1998) Engineering Criteria 2000.

The factor analysis yielded three gain factors: Gains in Group Skills (4 items), Gains in Problem-Solving Skills (12 items), and Gains in Occupational Awareness (4 items). The three-factor solution accounted for 64.4 percent of the variance in the correlation matrix. The internal consistency of the three scales was also high, ranging from .81 to .94. Appendix A lists items comprising each scale.

CLASSROOM PRACTICES AND LEARNING OUTCOMES

Classroom Climate

A comparison of means of students' perceptions of the way instructors treat female and male students revealed no gender-based disparate treatment ($t = - .514, p = .604$). However, minorities perceived faculty treated them differently than whites ($t = - 2.52, p < .05$). Results also show a chilly climate prompted by male and white students. Whether in the class as a whole, or working in groups, minorities and women felt unfairly treated by their white ($t = 5.7, p < .000$) and male ($t = 3.72, p < .000$) classmates.

Predictors of Learning Outcomes

Multiple regression analyses were performed to assess the significant predictors of self-reported gains in Group Skills, Problem-Solving Skills, and Gains in Professional Awareness. In all regression models the listwise option was employed.

To examine whether variation in student development had more to do with pre-course characteristics than with teaching practices, factors were grouped in two blocks and sequentially entered. The first block included measures of academic ability (SAT scores), motivation (highest degree expected), socioeconomic status (highest parental education), gender, ethnicity, division (freshman to senior), and perceptions of classroom climate. The second block included the three measures of instructional practices (Instructor Interaction and Feedback, Collaborative Learning, and Clarity and Organization).

Table 2 summarizes the results of the three regression analyses (one for each learning outcome). The first column depicts the proportion of variance explained in each learning outcome due to pre-college characteristics, motivation, and perceptions of climate. The second column reports the proportion of variance explained in each student learning outcome after adding instructional practices.

The last column documents the change in the value of $R^2$ accompanying the entry of the instructional activities variables set. It signifies the contribution of instructional practices to student learning above and beyond any differences in students' background or demographic characteristics or their perceptions of the classroom climate.

As can be seen in Table 2, the regression models explained 27 percent, 33.3 percent, and 25 percent of the variance in gains in Group Skills, Problem-Solving Skills, and Occupational Awareness (see column 3 in Table 2). Particularly
noteworthy is the fact that instructional practices accounted for most of those gains (see column 4 in Table 2). Teaching practices contributed to 23 percent, 31 percent, and 22 percent of the variance of gains in Group, Problem Solving, and Occupational Awareness. Students’ pre-college characteristics, class year, and classroom climate explained no more than 4 percent of the variations in skill development gains (see column 2 in Table 2).

Instructor Interaction and Feedback and Collaborative Learning were the two instructional practices that consistently predicted gains in all three professional competencies (see Table 3). The relative importance of the teaching practice, as determined by standardized betas, varied with the learning outcome under consideration. Instructional Interaction and Feedback was significantly and positively related to gains in Group Skills, Problem-Solving Skills, and Occupational Awareness. As might be expected, Collaborative Learning had the strongest (and positive) effect on students’ self-reported gains in their group skills. Collaborative Learning practices, however, were also positively and significantly related to gains in Problem Solving and Occupational Awareness. While gains in Group Skills were dominated by the use of collaborative techniques, results also show that active engagement on the part of the instructor is relevant. An instructor who interacts frequently with students in and outside the class, guides learning rather than lecturing, and provides detailed and frequent feedback on course assignments contributes to a student’s gains in Group Skills.

Clarity and Organization exerted positive and significant effects on all learning outcomes except gains in Group Skills. The more instructors explained their assignments and organized course material, the more students gained in problem-solving skills while becoming more aware of what engineering as an occupation was all about.

Students’ characteristics had relatively less effect on competencies than did teaching practices. The only relevant demographic-related finding was that males showed greater gains in Occupational Awareness than did females. High SAT scores negatively affected gains in Group Skills and Occupational Awareness. Upper division students showed fewer gains in Group Skills than did their lower division counterparts. Peer Classroom climate mattered for only one competency: Groups Skills. Exposure to a negative Peer Climate toward women and minorities reduced students’ gains in Group Skills regardless of their race, gender, ability, degree aspirations, and exposure to instructional practices. However, the relative effects of SAT scores, Peer Climate, and gender were small in relation to the effect exerted by instructional practices.

LIMITATIONS

Results of this study are limited in several ways. Generalization of findings to other colleges and universities should be approached with caution, as schools and students participating in the study were not randomly selected. Conse-
quently, the students and institutions comprising our sample may not be representative of the whole universe. Another limitation of this study has to do with the nature of learning itself. While learning is the outcome of a longitudinal process (Murray, 1991), our measures are based on a cross-sectional research design. Finally, our measures of gains are self-reported; objective tests may yield different results.

The study has several strengths, however. The sample is multi-institutional and large enough to support the use of sophisticated statistical analyses. The results themselves are consistent with the instructional practices literature (e.g., Murray, 1991) as well as with past research findings documenting the effect of active and collaborative learning on student learning (Tinto, 1997). The strategy followed in item development adds to the study’s internal consistency. Teaching practices were based on the literature, and they reflect observable behaviors rather than subjective impressions. The decision to use self-reported gains to gauge learning outcomes, instead of using objective cognitive tests, was based on several considerations. Many practical competencies, such as ability to work on groups, cannot be measured by objective tests. Furthermore, locally developed or standardized tests for engineering-related competencies are expensive and difficult to design. Finally, recent research suggests that self-report measures of learning can be used to appraise gains in cognitive skills. Pike (1995) found self-reported measures of educational gains to be as valid as objective measures to the extent to which the measures reflect the content of the learning outcome under consideration. Likewise, Anaya (1999), after examining a representative sample of students who took the GRE in 1989, concluded that self-reported measures of gains in cognitive skills are valid proxies of cognitive skills as measured by the verbal and math components of the GRE.

CONCLUSIONS

This article reports the results of a project aimed to create performance indicators for classroom practices and gains in professional competencies. These indicators were meant to assist the ECSEL coalition in evaluating their curriculum reform efforts. The article also documents the extent to which indicators of classroom practices can be used to predict gains in professional competencies among undergraduate engineering students.

The indicators meet several of the conditions recommended by the assessment literature. They are meaningful to the user in that their content is consistent with the objectives of ECSEL’s curricular reform objectives. The indicators are reliable and valid; each of the scales has reliabilities that fall in the high range. They also index gains in competencies deemed essential by the coalition of engineering schools. Moreover, classroom practices indicators are valid as they predict self-reported gains in competencies. The indicators are also consistent with recommendations from the literature on teaching effectiveness (e.g., Murray, 1991); they index observable behaviors (e.g., instructor gives frequent feedback) rather than subjective impressions (e.g., the instructor is caring).

Findings indicate that faculty efforts in the classroom indeed have important influences on student learning. An instructor who interacts with students, guides learning rather than lecturing, and gives detail and specific feedback and encouragement provides students with an important model for appropriate and positive collaborative behavior. Such an instructor gives students support and information necessary to learn how to solve problems and meet complex design processes. Those instructors who bring clarity and organization to the classroom also positively influence student development. Explaining assignments and activities, clearly stating course expectations, and articulating assignments to the content of the class not only increase the ability of students to solve problems but enhances their awareness of what the engineering occupation is all about.

The results of this study corroborate evidence from other research indicating that learning involves active participation of the faculty member in the use of active and collaborative instructional methods (Tinto, 1997). However, expectations that instructors would voluntarily commit to innovative learning strategies may not be warranted. Finkelstein, Seal, and Schuster (1998) found that more than three fourths of new and senior faculty rely on lecture as their primary—or even their only—teaching practice.

Structuring classroom activities to promote gains in occupational awareness, problem solving, and group skills is by nature complex. Developing assignments that call for learning by design coupled with the emphasis on constant feedback required specialized knowledge on the part of faculty that only constant training and substantial experience can provide. Such a commitment to professional development can be supported to the extent colleges and universities create and maintain centers for excellence in teaching. Faculty commitment is also unlikely when their reward system pays lip service to teaching. An assistant or associate professor confronting the competing demands for research and service would be hesitant to commit herself or himself to demanding instructional techniques if these activities are neglected in promotion and salary decisions.

Expectations on the part of accrediting agencies such as the Middle States Association of Colleges and Schools and ABET that institutions be accountable for developing students’ professional competencies may indeed encourage more widespread use of effective instructional techniques. Collaborative Learning and Instructor Interaction and Feedback, all of them endorsed by ABET, contributed significantly and substantially to student development among undergraduate engineering students. In addition to accreditation, our results suggest performance funding may be a viable strategy to foster change. Allocating resources based on demonstrable gains in professional competencies can indeed motivate institutions to adopt effective instructional techniques. As noted by Burke and Serban
(1998), a necessary condition for successful performance funding rests on the availability of reliable and valid indicators of student development, a condition that is met in our study.

While the nature of the classroom activity in itself important, the climate in which teaching takes place cannot be neglected. Mounting evidence suggests a negative association between collegiate experiences and minorities and women's self-confidence in pursuing science, math, and engineering majors (e.g., Drew, 1996; Seymour and Hewitt, 1997). In this regard, the finding that women and minorities do not feel treated with equity is most distressing. Equally troublesome is the finding that exposure to a peer chilly climate reduces students' gains in Group Skills. Training faculty in classroom management, handling of group conflict, and awareness of diverse learning styles should help create a positive classroom climate of respect for all students.

Acknowledgments. This study was supported in part by a grant from the Engineering Education and Centers Division of the National Science Foundation to Howard University (Grant No. 634066D) to support the Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL). The opinions expressed here do not necessarily reflect the opinions or policies of the National Science Foundation, and no official endorsement should be inferred. The authors would like to thank the editor and two anonymous reviewers for their invaluable comments and suggestions. Special thanks go to Michael Paulsen for his comments on an earlier version of this manuscript.

APPENDIX A. Scales' Item Composition

A. Instructional Practices: Collaborative Learning
   Discuss ideas with classmates
   Work cooperatively with students
   There are opportunities to work in groups
   Get feedback from classmates
   Students teach and learn from one another
   Interact with students in course outside of class
   Class activities require students to be active participants

B. Instructional Practices: Instructor Interaction & Feedback
   Interact with instructor as part of the course
   Interact with instructor outside of class
   Instructor guides learning, rather than lecturing
   Instructor gives detailed feedback on work
   Instructor gives frequent feedback on work

C. Instructional Practices: Clarity & Organization
   Assignments and class activities clearly explained
   Assignments and class activities are interrelated
   Instructor makes clear expectations of activities

D. Classroom Climate: Faculty Climate
   Instructor treats minorities the same way as whites
   Instructor treats women the same way as men

E. Classroom Climate: Peer Climate
   In groups, some males treat women differently
   Some male students treat women differently
   Some white students treat minorities differently
   In groups, some white students treat minorities differently

F. Professional Competencies: Group Skills (Progress made as a result of the course in:)
   Developing ways to resolve conflict and reach agreement
   Being aware of feelings of members in group
   Listening to ideas of others with open mind
   Working on collaborative projects as member of a team

G. Professional Competencies: Problem-Solving Skills (Progress made as a result of the course in:)
   Ability to do design
   Solve an unstructured problem
   Identify knowledge, resources, and people to solve problem
   Evaluate arguments and evidence of competing alternatives
   Apply an abstract concept or idea to a real problem
   Divide problems into manageable components
   Clearly describe a problem orally
   Clearly describe a problem in writing
   Develop several methods to solve unstructured problems
   Identify tasks needed to solve an unstructured problem
   Visualize what the product of a design project would look
   Weigh the pros and cons of possible solutions to a problem

H. Professional Competencies: Occupational Awareness (Progress made as a result of the course in:)
   Understanding what engineers do
   Understanding the language of design
   Understanding engineering has a nontechnical side
   Understanding the process of design
### APPENDIX B. Correlations Between Predictors and Gains in Group Skills

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gender</td>
<td>1</td>
<td>-0.073</td>
<td>-0.053</td>
<td>-0.033</td>
<td>-0.042</td>
<td>0.042</td>
</tr>
<tr>
<td>2. African American</td>
<td>-0.073</td>
<td>1</td>
<td>-1.141(*)</td>
<td>-0.065</td>
<td>-0.049</td>
<td>-0.273(*)</td>
</tr>
<tr>
<td>3. Asian American</td>
<td>-0.053</td>
<td>-1.141(*)</td>
<td>1</td>
<td>-1.108(**)</td>
<td>-0.061</td>
<td>0.009</td>
</tr>
<tr>
<td>4. Hispanic</td>
<td>-0.033</td>
<td>-0.065</td>
<td>-1.108(**)</td>
<td>1</td>
<td>-0.06</td>
<td>-0.02</td>
</tr>
<tr>
<td>5. Highest parent. ed.</td>
<td>-0.042</td>
<td>-0.049</td>
<td>-0.061</td>
<td>-0.06</td>
<td>1</td>
<td>0.275(**)</td>
</tr>
<tr>
<td>6. SAT</td>
<td>0.042</td>
<td>-0.273(**)</td>
<td>0.009</td>
<td>-0.02</td>
<td>0.275(**)</td>
<td>1</td>
</tr>
<tr>
<td>7. Highest deg. exp.</td>
<td>-0.084(*)</td>
<td>0.132(**)</td>
<td>0.067</td>
<td>-0.042</td>
<td>0.176(**)</td>
<td>0.238(**)</td>
</tr>
<tr>
<td>8. Division</td>
<td>0.100(*)</td>
<td>-0.048</td>
<td>-0.073</td>
<td>-0.003</td>
<td>-0.142(**)</td>
<td>-0.383(**)</td>
</tr>
<tr>
<td>9. Faculty Climate</td>
<td>0.05</td>
<td>-0.01</td>
<td>-0.107(*)</td>
<td>-0.045</td>
<td>-0.032</td>
<td>0.085(*)</td>
</tr>
<tr>
<td>10. Peer Climate</td>
<td>-0.083</td>
<td>0.052</td>
<td>0.078</td>
<td>0.012</td>
<td>-0.009(*)</td>
<td>-0.048</td>
</tr>
<tr>
<td>11. Interact. &amp; Feed.</td>
<td>0.021</td>
<td>0.037</td>
<td>-0.056</td>
<td>-0.031</td>
<td>-0.005</td>
<td>0.081</td>
</tr>
<tr>
<td>12. Collaborative Learn.</td>
<td>-0.071</td>
<td>-0.061</td>
<td>-0.042</td>
<td>0.002</td>
<td>0.054</td>
<td>0.228(**)</td>
</tr>
<tr>
<td>13. Clarity &amp; Organization</td>
<td>0.058</td>
<td>0.056</td>
<td>-0.076</td>
<td>0.036</td>
<td>-0.017</td>
<td>0.004</td>
</tr>
<tr>
<td>14. Gains in Group Skills</td>
<td>-0.018</td>
<td>-0.042</td>
<td>0.029</td>
<td>-0.007</td>
<td>0.013</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*Listwise N = 564.
**Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

### APPENDIX B. (Continued) Correlations Between Predictors and Gains in Problem Solving Skills

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gender</td>
<td>1</td>
<td>-0.066</td>
<td>-0.057</td>
<td>-0.036</td>
<td>-0.055</td>
<td>0.055</td>
</tr>
<tr>
<td>2. African American</td>
<td>-0.066</td>
<td>1</td>
<td>-1.138(**)</td>
<td>-0.065</td>
<td>-0.044</td>
<td>-0.269(**)</td>
</tr>
<tr>
<td>3. Asian American</td>
<td>-0.057</td>
<td>-1.138(**)</td>
<td>1</td>
<td>-1.108(*)</td>
<td>-0.069</td>
<td>-0.003</td>
</tr>
<tr>
<td>4. Hispanic</td>
<td>-0.036</td>
<td>-0.065</td>
<td>-1.108(*)</td>
<td>1</td>
<td>-0.061</td>
<td>-0.019</td>
</tr>
<tr>
<td>5. Highest parent. educ.</td>
<td>-0.055</td>
<td>-0.044</td>
<td>-0.069</td>
<td>-0.061</td>
<td>1</td>
<td>0.279(**)</td>
</tr>
<tr>
<td>6. SAT</td>
<td>0.055</td>
<td>-0.269(**)</td>
<td>-0.003</td>
<td>-0.019</td>
<td>0.279(**)</td>
<td>1</td>
</tr>
<tr>
<td>7. Highest Deg. Exp.</td>
<td>-0.075</td>
<td>0.128(**)</td>
<td>0.069</td>
<td>-0.04</td>
<td>0.185(**)</td>
<td>0.243(**)</td>
</tr>
<tr>
<td>8. Division</td>
<td>0.094(*)</td>
<td>-0.046</td>
<td>-0.068</td>
<td>-0.005</td>
<td>-0.150(**)</td>
<td>-0.384(**)</td>
</tr>
<tr>
<td>9. Faculty Climate</td>
<td>0.053</td>
<td>-0.003</td>
<td>-1.108(*)</td>
<td>-0.046</td>
<td>-0.032</td>
<td>0.081</td>
</tr>
<tr>
<td>10. Peer Climate</td>
<td>-0.063</td>
<td>0.039</td>
<td>0.085(*)</td>
<td>0.014</td>
<td>0.098(*)</td>
<td>-0.053</td>
</tr>
<tr>
<td>11. Instructor Interac. &amp; Feed.</td>
<td>0.022</td>
<td>0.031</td>
<td>-0.051</td>
<td>-0.032</td>
<td>-0.009</td>
<td>0.089(*)</td>
</tr>
<tr>
<td>12. Collab. Lear.</td>
<td>-0.064</td>
<td>-0.063</td>
<td>-0.04</td>
<td>0.003</td>
<td>0.047</td>
<td>0.226(**)</td>
</tr>
<tr>
<td>13. Clarity &amp; Organization</td>
<td>0.06</td>
<td>0.053</td>
<td>-0.075</td>
<td>0.038</td>
<td>-0.021</td>
<td>0.004</td>
</tr>
<tr>
<td>14. Gains in Prob. Solv.</td>
<td>0.056</td>
<td>0.04</td>
<td>-0.048</td>
<td>0.008</td>
<td>-0.008</td>
<td>0.011</td>
</tr>
</tbody>
</table>

*Listwise N = 559.
*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).
## APPENDIX B. (Continued) Correlations Between Predictors and Gains in Occupational Awareness

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gender</td>
<td>1</td>
<td>-0.074</td>
<td>-0.045</td>
<td>-0.018</td>
<td>-0.046</td>
<td>0.039</td>
</tr>
<tr>
<td>2. African American</td>
<td>-0.074</td>
<td>1</td>
<td>-1.40(**)</td>
<td>-0.064</td>
<td>-0.05</td>
<td>-0.272(**)</td>
</tr>
<tr>
<td>3. Asian American</td>
<td>-0.045</td>
<td>-1.40(**)</td>
<td>1</td>
<td>-1.06(*)</td>
<td>-0.06</td>
<td>0.006</td>
</tr>
<tr>
<td>4. Hispanic</td>
<td>-0.018</td>
<td>-0.064</td>
<td>-1.06(*)</td>
<td>1</td>
<td>-0.064</td>
<td>-0.011</td>
</tr>
<tr>
<td>5. Highest paren. educ.</td>
<td>-0.046</td>
<td>-0.05</td>
<td>-0.06</td>
<td>-0.064</td>
<td>1</td>
<td>0.276(**)</td>
</tr>
<tr>
<td>6. SAT</td>
<td>0.039</td>
<td>-1.272(**)</td>
<td>0.006</td>
<td>-0.011</td>
<td>1.276(**)</td>
<td>1</td>
</tr>
<tr>
<td>7. Highest Degr. Expect.</td>
<td>-0.00(*)</td>
<td>0.131(**)</td>
<td>0.067</td>
<td>-0.041</td>
<td>1.199(**)</td>
<td>0.244(**)</td>
</tr>
<tr>
<td>8. Division</td>
<td>0.100(*)</td>
<td>-0.048</td>
<td>-0.07</td>
<td>0.002</td>
<td>-1.43(**)</td>
<td>-0.388(**)</td>
</tr>
<tr>
<td>9. Faculty Climate</td>
<td>0.051</td>
<td>-0.01</td>
<td>-1.09(**)</td>
<td>-0.049</td>
<td>-0.031</td>
<td>0.883(*)</td>
</tr>
<tr>
<td>10. Peer Climate</td>
<td>-0.00(*)</td>
<td>0.05</td>
<td>0.074</td>
<td>0.01</td>
<td>-0.689(*)</td>
<td>-0.049</td>
</tr>
<tr>
<td>11. Instruct. Interac. &amp; Fed</td>
<td>0.021</td>
<td>0.037</td>
<td>-0.061</td>
<td>-0.028</td>
<td>-0.009</td>
<td>0.08</td>
</tr>
<tr>
<td>12. Collab. Learn.</td>
<td>-0.069</td>
<td>-0.059</td>
<td>-0.041</td>
<td>0.002</td>
<td>0.048</td>
<td>0.226(**)</td>
</tr>
<tr>
<td>13. Clarity &amp; Organization</td>
<td>0.056</td>
<td>0.058</td>
<td>-0.078</td>
<td>0.036</td>
<td>-0.019</td>
<td>0.003</td>
</tr>
<tr>
<td>14. Gains in Occup. Awar.</td>
<td>0.100(*)</td>
<td>0.024</td>
<td>-0.016</td>
<td>0.01</td>
<td>-0.061</td>
<td>-0.076</td>
</tr>
</tbody>
</table>

*Listwise N = 565.

**Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

### NOTES

1. This estimate is based on a 1997 telephone survey of all state higher education finance officers in the 50 states, Puerto Rico, and the District of Columbia.
2. Listwise selection of cases eliminated all those cases for which there were missing values. Appendix B displays the correlation matrices employed in the analyses.

### REFERENCES


Received January 19, 1999.