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TIGHTENING CURRICULAR COHESION: THE INFLUENCE OF FACULTY CONTINUOUS IMPROVEMENT ACTIVITIES ON STUDENT LEARNING

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ABSTRACT

Over the past decade, continuous improvement has emerged as a strategy for documenting and systematically building academic program quality. This study examines the influence of faculty members' continuous improvement activities (as reflected in curriculum planning, instructional development, projects to improve undergraduate education, and participation in assessment) on the relationships between student and institutional characteristics, student experiences in- and out-of-class, and student learning outcomes. While there is an extensive literature related to the application of continuous improvement and the implementation of assessment, few studies have empirically explored the link between continuous improvement and student learning. This study uses a nationally representative sample of engineering faculty members and students to explore this link. In phase I, engineering programs were grouped based on their status as high or low continuous improvement programs. In phase II hierarchical models explored the direct effect of continuous improvement on student learning outcomes, controlling for student and institutional characteristics. In phase III, a multiple-group path analysis explored the indirect effects of continuous improvement through a multiple group analysis in which the conceptual model was fit to the data for the high and for the low programs separately.

The result of the cluster analysis validated the use of the four continuous improvement variables to differentiate engineering programs into high and low continuous improvement groups. Group membership, however, was not a significant influence on student learning in the two-level hierarchical model tested, and program-level variance was small, suggesting that a single-level model with students as the unit of analysis was appropriate and that the influence of continuous improvement on student outcomes is likely an indirect one. The path models for the high and low groups differed significantly, supporting the hypothesis that continuous improvement indirectly influences the relationships between student and institutional characteristics, student experiences, and student learning outcomes. Further, the path results suggested a number of conceptually supportable modifications to the analytical and conceptual frameworks used in the study. These modifications suggest that the relationship between student experiences and student outcomes is not unidirectional, as originally conceptualized, and that relationships between different experiences and between different outcomes deserve further attention.

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Chapter 1

INTRODUCTION

In the 1980s and 1990s, public skepticism toward higher education grew at an alarming pace. A series of critical reports and books charged that higher education was unresponsive to the needs of undergraduate students, and that the quality of American higher education was declining (Association of American Colleges, 1985; W. J. Bennett, 1984; Bloom, 1987; D´Souza, 1991; Sykes, 1988). The increasing cost of higher education, growing competition for state and federal dollars, and much-publicized critiques of undergraduate education stimulated calls for accountability and improvement in program review processes (Harcleroad, 1980). Legislators and other constituents of higher education began to demand greater accountability from public colleges and universities (Haworth & Conrad, 1996) and to question the efficacy of educational accrediting standards (Bollag, 2005). Accreditors responded by shifting from input-based accreditation standards to a focus on assessment of student learning outcomes[1] and some specialized accreditors also adopted assessment's corollary process – continuous quality improvement (CQI).[2]

Continuous quality improvement focuses on setting objectives, measuring outcomes, and using the findings from this assessment to improve the processes responsible for these outcomes (Deming, 1982; Juran, 1988). CQI evolved from total quality management (TQM), a business model popularized in the 1980s by such giants as Xerox and Ford (Gabor, 1990). Despite the titular change, many academics were, and remain, suspicious of CQI efforts in higher education.

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[1] See standards of (Middle States Commission on Higher Education, 2006; New England Association of Schools and Colleges Commission on Institutions of Higher Education, 2005; North Central Association of Colleges and Schools Higher Learning Commission, 2003; Northwest Commission on Colleges and Universities, n. d.; Southern Association of Colleges and Schools, 2008; Western Association of Schools and Colleges, 2006).

[2] See standards for engineering (ABET, 1997), Nursing (National League for Nursing Accreditation Commission, 2006), and Business (Association to Advance Collegiate Schools of Business International, 2006).

Faculty members accustomed to relative autonomy within their institutions often resist the top-down focus of CQI principles such as assessment-driven decision making, customer satisfaction, and benchmarking, (Ensby & Mahmoodi, 1997; Marchese, 1993; Stark & Lattuca, 1997; Tener, 1999). Chambers and Ferndandez (2004) suggest that faculty who resist continuous improvement[3] efforts do so because they cannot reconcile quality principles with their concepts of the dynamic nature of knowledge, the simultaneous role of students as customers, employees, and outcomes, and the use of subjective student satisfaction surveys as a measure of teaching quality.

Despite the reluctance of faculty to embrace continuous improvement, both regional and specialized accrediting bodies are beginning to incorporate its principles into their accreditation criteria. Today, CQI approaches are increasingly implemented in academic programs and in some cases have been mandated as part of academic program review and accreditation processes (American Association for Higher Education, 1994; Hubbard, 1993; Lohmann, 1999). Between 1998 and 2001, ABET, Inc. (formerly the Accreditation Board for Engineering Technology) began a phased implementation of a new set of accreditation criteria for undergraduate engineering programs (Prados, Peterson, & Lattuca, 2005). The new criteria, designated *Engineering Criteria 2000* (EC2000), minimized the detailed specification of curricula and resources, focusing instead on documenting student learning outcomes and on the use of student assessment to facilitate continuous improvement (ABET Engineering Accreditation Commission, 1997). In October 2005, a research team commissioned by ABET reported the results of a study, entitled *Engineering Change: A Study of the Impact of EC2000* (Lattuca, Terenzini, & Volkwein, 2006a). Overall, graduates prepared in engineering programs accredited under EC2000 reported higher learning outcomes than those educated in the same programs before EC2000's

[3] Because the terms TQM, CQI, and continuous improvement are used interchangeably in much of the higher education literature, the term "continuous improvement" will be used throughout this paper to refer to these philosophies and practices inclusively.

implementation. Further, the *Engineering Change* study found evidence linking some types of program changes to improvements in student learning. Although those findings lend support to the use of an outcomes-based accreditation model, researchers have yet to specifically examine the effects of continuous improvement activities on learning outcomes.

In response to growing demands for accountability, as well as changing accreditation requirements, colleges and universities are investing considerable resources to implement continuous improvement-based reforms in academic programs. Despite a large body of literature on the advantages of implementing continuous improvement, the trend towards mandating continuous improvement is rapidly gaining momentum without the benefit of any systematic, empirical exploration of its connection to student learning. The *Engineering Change* study broke new ground in this regard, exploring the relationships among activities such as changes in curricula and pedagogy and the use of assessment for curriculum planning, student experiences, and student learning. This study built on that foundation and moved the research base forward by focusing squarely on the impact of the continuous improvement component of the EC2000 criteria on student experiences and learning.

The *Engineering Change* database provides a number of measures of faculty culture that were used to gauge the level of continuous improvement practiced by engineering program faculty. These include measures of: 1) assessment activities, 2) faculty support for continuous improvement, 3) continuous curriculum planning, and 4) professional development efforts. Each is a key element of an effective continuous improvement process.

Assessment is a key component of continuous improvement. Assessment identifies problem areas and provides a benchmark by which to gauge change (Seymour, 1992). The assessment movement in higher education has gained momentum over the past three decades, increasing use of assessment data to facilitate academic program review as a quality control and improvement measure (Banta, 2002; Creamer & Janosik, 1999). Despite the attention devoted to assessment in the higher education literature and in countless workshops and conferences, its incorporation into academic program review is still in the adoption phase. Unlike institutional assessment, which occurs regularly and predictably through the accreditation process, program review often occurs erratically and in response to a perceived problem rather than being ongoing and systematic. When program review does occur, institutions often focus on the process (i.e., gathering and presenting the data) and "do little with the results" (Creamer & Janosik, 1999).

In academic departments, the primary responsibility for assessment and program review often lies with faculty members, but many faculty members have been reluctant to embrace continuous improvement. Although ABET requires the use of continuous improvement strategies in accredited engineering programs, this mandate may not be embraced equally by all institutions and engineering programs, making levels of assessment activity and faculty attitudes towards such activities valuable metrics of continuous improvement.

The curriculum provides the key structural framework through which students learn and grow in college, and the incorporation of ongoing feedback should be a part of ongoing curriculum review and revision (Stark & Lattuca, 1997). Yet curriculum planning takes place only periodically, often as part of a required strategic planning effort or accreditation site visit (Anderson & Ball, 1978; Conrad & Wilson, 1985). Although curriculum planning is a core component of continuous improvement in academic programs, few faculty have training in curriculum development or revision, making it difficult for them to implement the feedback they receive about student learning (Wankat, Felder, Smith, & Oreovicz, 2002). In addition, faculty members often lack the training to extend their assessment activities beyond traditional measures such as exams and term papers.

Recognizing the limitations of their discipline-focused training, faculty committed to continuous improvement can be expected to engage in activities that enhance their ability to assess student learning. Further, they are likely to incorporate that assessment into curriculum planning in order to continually improve the quality of teaching and learning that takes place in their classrooms and their programs. Subsequently, an important measure of faculty commitment to continuous improvement is participation in professional development activities that focus on assessment, course development, and course improvement. The success of such activities, however, cannot be measured by level of faculty participation or commitment, but rather in terms of the ultimate outcome of all educational endeavors – student learning.

Using measures of curriculum planning, instructional development, participation in research focused on undergraduate education, and participation in assessment from the *Engineering Change* database to operationalize continuous improvement, this study addresses the following research questions:

1. Do programs differ measurably on these continuous improvement variables?
2. If programs can be differentiated by their level of continuous improvement, is this aspect of program culture directly related to student learning outcomes?
3. Does continuous improvement level influence the nature of the relationships between student pre-college characteristics, institutional characteristics, student experiences, and student outcomes?

Context of the Study

Academic program review has historically functioned as a tool for reforming and revitalizing the curriculum (Conrad & Wilson, 1985), but it has also been a largely reactive process, undertaken when budgets are tight, a new program is needed, a problem emerges, or when mandated by accreditation bodies and state education departments. Although institutions and academic programs that receive specialized accreditation (e.g., engineering, nursing, business, forestry) undergo periodic program reviews for a variety of reasons (e.g. program creation/elimination, strategic planning, budgeting), one major impetus for such resource-intensive efforts is the requirements of accrediting bodies. As institutions and accreditors have faced calls for increased accountability, both have sought new ways to improve academic programs and demonstrate their educational value. Continuous improvement is a strategy increasingly employed by accreditors and institutions to reform the program review process.

Program Review

The history of academic program evaluation goes back to the foundations of American higher education, but the practice became more common and systemic in the latter part of the 20th century (Harcleroad, 1980). During the 1970s, the number of institutions using some form of academic program review grew expansively, and by the end of that decade 82 percent of the institutions in a national survey reported using some type of formal program review activity (Barak, 1982). While that number was most likely an overestimate due to ambiguity surrounding the term "program review," it appears that by the end of the 20th century the majority of American higher education institutions had implemented a process of formal academic program review.

In the broadest sense, the purpose of an academic review is most often to assess the quality of academic programs. Historic views of program quality focused primarily on inputs such as SAT scores and library holdings (Astin, 1991; Haworth & Conrad, 1997). The assumption underlying this approach is that such resources are an indirect measure of a program's ability to produce quality outcomes. The major weaknesses in this type of program review are that it fails to: 1) evaluate achievement of those outcomes and 2) take into account differences in outcomes related to program goals and missions. Recent views on program evaluation, such as those expressed by a leader in the assessment movement (Astin, 1991) and by the Council of Higher Education Accreditation in its 2003 *Statement of Mutual Responsibilities for Student*

Learning Outcomes, have switched the focus from educational inputs to outputs. As a result, outcomes-based assessment has taken center stage as a technique for monitoring program quality.

Accreditation

Unlike most other countries, the United States has no central ministry of education responsible for overseeing institutions of higher education (Young & Chambers, 1980). Instead, a voluntary accreditation process relies on the academic principles of peer-review in order to ensure program quality. Typically, accreditation requires both an internal and external program peer review (Barak, 1982; Volkwein, Lattuca, Caffrey, & Reindl, 2003). Internal reviews are those undertaken by the program or institution under evaluation. The self-studies produced through internal reviews are provided to an external review team, commissioned by the accrediting body. This visiting team of volunteers from outside the institution conducts an external review. The nature of both the internal and external reviews depends on the level of the accreditation – institutional-level by a regional accreditor or program-level by a specialized accreditor.

Six regional accrediting bodies (New England, Middle States, Southern, North Central, Northwest, and Western) oversee institutional accreditation of colleges and universities. These reviews are “comprehensive in scope, covering an institution’s financial status, governance, faculty and staff relations and achievements, student services, and student learning outcomes” (Volkwein et al., 2003, p. 10) and typically occur in cycles of five to ten years. The vast majority (2,986) of the nations’ colleges and universities hold regional accreditation (Council for Higher Education Accreditation, 2006a). While some institutions offer a quality education but do not seek accreditation because of inherent conflicts between accreditation standards and their mission (for example, some faith-based institutions), regional accreditation is widely recognized as the primary indicator of a legitimate institution of higher education in the United States. Accreditation is required for an institution to participate in federal grants and programs, receive state operating funds, and for its students to receive federal and state financial aid (Council for Higher Education Accreditation, 2006b).

Specialized accreditation recognizes specific fields of study, such as engineering, accounting, and nursing, and is overseen by a variety of discipline-specific organizations. Specialized accreditation is available in 100 fields of study and many academic programs coordinate their own internal program review processes with the criteria of their accreditation requirements (Volkwein et al., 2003). Specialized accreditors recognize 18,152 majors, professional programs, and schools (e.g., law schools, nursing schools); ABET accredits 2,728 engineering programs nationwide (Council for Higher Education Accreditation, 2006a).

While U.S. institutions are not required to seek regional or specialized accreditations, they are a widely accepted recognition of quality and are required for many types of professional licensure and for institutional participation in many state and federal programs. Today, some federal legislators view accreditation as the obvious instrument for increasing institutional accountability to stakeholders. From 2003 to 2007, debates over the reauthorization of the Higher Education Act included suggestions for increased national oversight of the accreditation process (American Council of Trustees and Alumni, 2007; Bollag, 2005; Commission on the Future of Higher Education, 2006b). The prospect of increased government involvement, combined with recognition of the weaknesses of past approaches to program evaluation, has stimulated considerable interest in outcomes-based assessment as a method for documenting program effectiveness.

Continuous Improvement

In recent years, both regional and specialized accrediting bodies have embraced outcomes-based assessment (Cabrera, Colbeck, & Terenzini, 2001; Council for Higher Education Accreditation, 2003). In contrast to earlier emphases on resources and reputations, this type of assessment monitors outputs, rather than inputs. Initially, institutions of higher education borrowed the tenets of continuous improvement from business and industry to manage their administrative and support units (Chaffee & Sheer, 1992; Schwartzman, 1995). As academic programs came under increasing criticism and views of quality began to change, many institutions realized that continuous improvement could also help them reach their curricular and program goals as well (Salegna & Bantham, 2002). This shift occurred largely through the influence of specialized accrediting agencies.

Those accreditors with close ties to industries in which continuous improvement efforts have become *de rigueur*, such as business, engineering, and nursing, have been among the first to incorporate the tenets of continuous improvement into the curriculum component of their accreditation standards (see, for example, Association to Advance Collegiate Schools of Business International, 2006; National League for Nursing Accreditation Commission, 2006). Some accrediting bodies, including those for engineering and medical schools, have even identified specific learning outcomes to be achieved by the graduates of all accredited programs (Volkwein, Lattuca, Harper, & Domingo, 2007). ABET's EC2000 accreditation standards not only require the application of continuous improvement to academic programs, but further require programs to achieve a list of educational objectives, establish additional individualized program objectives, and demonstrate program outcomes (ABET Engineering Accreditation Commission, 2005). The continuous improvement efforts and common set of educational objectives mandated by EC2000, make ABET-accredited engineering programs an ideal population for the study of the influence of continuous improvement on student learning.

Justification for the Study

Purpose of the Study

The main premise of applying continuous improvement to academic programs is that it will improve student learning (the "product" or "outcome" in continuous improvement terms). To date, much of the research literature relating to continuous improvement in higher education has focused on its application in the administrative units of colleges and universities and has been largely descriptive or prescriptive in nature (see for example, Hubbard, 1993; Seymour, 1992). As researchers and practitioners are beginning to see its applicability in curriculum and course-level reform, colleges and universities are investing time, money, and human resources into implementing continuous improvement in these areas (Brawner, Anderson, Zorowski, & Serow, 2001; Salegna & Bantham, 2002). Yet, this investment of resources has occurred without an empirical analysis of the benefits of continuous improvement activities. Accreditors and institutional administrators do not know whether continuous improvement activities are enhancing student learning or if limited resources should be diverted to other activities more closely related to student learning.

The purpose of this study is to examine how specific continuous improvement activities (such as assessment and the use of assessment data for decision-making) affect students in college. It will test the efficacy of using continuous improvement metrics to differentiate engineering programs and then use these differences to explore the nature of their effects on students in college. If, as ABET's EC2000 criteria imply, continuous improvement efforts will improve the learning experience of students, then student experiences should have a stronger influence on student learning outcomes, after controlling for student pre-college characteristics and institutional variables, in those accredited engineering programs that demonstrate high levels of continuous improvement activities than in those that do not. Using hierarchical linear modeling, the study will reveal whether continuous improvement activities have a direct effect on learning, or whether their influence is indirect, that is, whether CI affects student learning via its influence on students' educational experiences.

As accreditors increasingly incorporate continuous improvement into their standards and institutions increasingly implement continuous improvement activities into curriculum review and reform, the influence on student learning outcomes remains unknown. If continuous improvement efforts are related to enhanced student learning, then reluctant faculty members and program administrators may be persuaded to support continuous improvement activities with increased confidence and enthusiasm. However, if continuous improvement efforts do not appear to affect student learning positively, it may suggest that limited resources should be directed towards other avenues for program improvement.

Implications for Practice

As academic programs such as those in engineering and business follow the lead of their industry counterparts by implementing continuous improvement processes presumed to document and improve educational quality, empirical studies on their effects are required to justify the outlay of human and financial resources. Moreover, in the spirit of a "quality" philosophy that incorporates assessment for improvement, educational outcomes should be measured in order to assess the efficacy of continuous improvement efforts. In addition to influencing faculty commitment to assessment and continuous improvement, the results of such inquiries may provide practical information for faculty and administrators seeking to enhance practices associated with program review and undergraduate education.

Although this study uses an engineering sample, the results may apply to faculty more broadly. Tener (1999) argues that some characteristics of engineering faculty culture, such as resistance to change, individualism, incongruence between rewards and motivations, and resistance to the management jargon of continuous improvement, may inhibit outcomes-based assessment efforts. At the same time, Tener notes that some engineering faculty characteristics such as valuing quality, empowered faculty, and desire for validation of their efforts may in fact support the movement towards outcomes assessment and continuous improvement. Although Tener writes about engineering, the characteristics he describes apply to faculty more generally (see Carothers, 1995; Marchese, 1995; Olian, 1995). If engineering faculty culture does not differ substantially from that in other disciplines, the results of this study may be more applicable to other programs than apparent at first glance. Generalizations based on the results of this study to faculty outside of engineering should be undertaken with caution, however, until additional research with non-engineering faculty is able to support the application of these results outside of engineering.

Implications for Policy

In addition to the implications for individual departments and institutions implementing or considering implementation of continuous improvement at the academic program level, the results of this study may also inform public policy discussions about the efficacy of continuous improvement criterion in both regional and specialized accreditation standards. If ABET's effort to ensure the quality of baccalaureate engineering programs through the implementation of quality improvement principles is a success, then other specialized accrediting bodies, such as those for business and nursing, that have moved in this direction (e.g., Association to Advance Collegiate Schools of Business International, 2006; National League for Nursing Accreditation Commission, 2006) may find increased faculty and institutional support for their efforts. In addition, regional and specialized accrediting bodies that have embraced outcomes assessment may consider adding a continuous improvement component to their existing requirements or strengthening existing evidence-based improvement requirements (Volkwein et al., 2003).

Interest in improving accreditation practices, however, is not limited to the community of higher education practitioners and accreditors. During debates in 2003-2007 over the reauthorization of the Higher Education Act (Higher Education Act, 1965, as amended in 1998), members of Congress raised a number of questions about the rigor of existing accreditation practices in higher education. Such concerns have led to proposals (unsuccessful to date) to decouple financial aid eligibility and accreditation, to release accreditation findings to the public, and to require colleges to accept transfer credits from any postsecondary institution regardless of the source of its accreditation (Bollag, 2005, 2006; Brush, 2005). A draft report issued in 2006 by the U. S. Secretary of Education's Commission on the Future of Higher Education went so far as to suggest the establishment of a "national accreditation framework" (p. 23) which would require institutions to demonstrate evidence of student learning and "embrace a culture of continuous innovation and quality improvement" (p. 20). This proposal was ultimately excised from the report, but efforts to overhaul accreditation consider receiving attention.

Many in higher education view such provisions as detrimental to educational quality. The publication of accreditation reports has great potential for misinterpretation of such information by the public, and the forced acceptance of transfer credits threatens educational integrity (Bollag, 2005). Opponents to government intrusions argue that increased oversight of higher education by non-experts seeking simple solutions to complex issues threatens the foundation of America's highly respected system of higher education. Accreditation has been a voluntary process for more than a century, and many find such proposals unnecessarily intrusive and counterproductive. Regulations to increase federal oversight of the accreditation process are, they argue, "tantamount to the federal government's asserting authority over curriculum" (Basken, 2007, p. 20).

Accreditation agencies, both regional and specialized, must convincingly demonstrate that their processes ensure educational quality or open themselves and their client institutions to public scrutiny and legislative control. As these bodies increasingly embrace an outcomes-based, quality improvement model, the efficacy of such a model should be tested in order to validate its use. Initial evidence indicates that this model, as implemented by ABET, can be effective, but more analysis is need to understand the nature of continuous improvement in the model and its effects on student learning (Lattuca, Terenzini, & Volkwein, 2005, October). The results of this study will shed light on the continuous improvement aspect of the model in order to provide evidence regarding its influence on student experiences and outcomes.

Contribution to Future Research and Theory Building

While a large body of literature on continuous improvement exits both within higher education and in industry, it is largely a practitioner's literature that "sells" the philosophy and prescribes its implementation (see for example, Crosby, 1979; Deming, 1982; Juran, 1988). Few empirical studies have explored its application in academic programs, and none have focused on its influence on student learning. This study will help to build an empirically based model of the effects of continuous improvement on student learning and provide a strong foundation for further testing of the linkages between continuous improvement and student learning.

The findings will also contribute to the curriculum planning literature and to its application in engineering programs. The growing literature in this area is based on the intuitive assumption that curriculum planning is beneficial to student learning. If curriculum planning improves programs, then ongoing (rather than sporadic) planning efforts, such as those espoused by proponents of continuous improvement, should be especially effective. This study will test that basic assumption as it applies to curriculum planning in engineering. Further, this study will explore multiple aspects of curriculum development, as practiced by faculty, including planning, assessment, professional development related to curriculum and teaching, and faculty attitudes towards continuous improvement, allowing for some conclusions about the relative affects of each, individually and in combination, on student learning.

By testing the potential influences of continuous improvement on student learning, this study will contribute to the development of a complex model of student outcomes. Three decades of research on student outcomes has focused narrowly on small subsets of the student experience, such as the curriculum, classroom experiences, or co-curricular activities (Lambert, Terenzini, & Lattuca, 2006; Pascarella & Terenzini, 2005). While these studies have provided valuable clues for educators, they often fail to account for the complex interactions between student pre-college characteristics (high school preparation, parents' education, family income, etc.), institutional characteristics (both structural and cultural), student experiences in- and out-of-class, and learning (Pascarella & Terenzini, 1991, 2005).

This study will join such notable exceptions such as the *Engineering Change Study* (Lattuca et al., 2006a), the *National Study of Student Learning* (Pascarella et al., 1996; Reason, Terenzini, & Domingo, 2007; Springer, Terenzini, Pascarella, & Nora, 1995; Terenzini, Springer, Pascarella, & Nora, 1995) and the *National Survey of Student Engagement* (Kuh, 2001) in helping to build a more complete picture of how college affects student learning (Lambert et al., 2006). As accrediting criteria, government regulations, and university strategic planning processes mandate the incorporation of continuous improvement practices academic program planning, this study is a timely exploration of the effects of these practices on student learning.

The literature review in chapter two explores the application of continuous improvement principles to curriculum planning to colleges and universities. Section one will describe the foundations of continuous improvement and its congruence with recommended curriculum planning processes. Because assessment is a key component of the application of continuous improvement principles to curriculum planning, section two reviews the arguments for outcomes assessment. Section three closes the review by evaluating curriculum planning as an aspect of faculty culture, describes common and uncommon curriculum planning processes (including the use of assessment as part of the planning process), and highlights the untested assumptions of the benefits of curriculum inherent in the existing literature.

Chapter three explores the conceptual model and analytical framework that guide this study and describes the study methods and analysis. Recognizing the importance of students' educational experiences as a potential intervening variable between curriculum planning and learning outcomes, the framework incorporates important aspects of students' in- and out-of-class experiences as mediating variables. By exploring the connections between faculty practices and attitudes, students' experiences, and learning outcomes, this study will contribute to our understanding of these linkages, and to the evolution of more complex models of student experience and learning. Chapter four reports the findings of each stage of the analysis, and chapter five provides discussion of the results, conclusions and implication for practice, policy, and theory-building. This chapter also describes the limitations of the study and closes with recommendations for future research.

Chapter 2

LITERATURE REVIEW

Proponents of continuous improvement in academic programs base their ideas on the assumption that continuous improvement will lead to positive educational experiences for undergraduate students and to improved student learning outcomes. In the continuous improvement framework, improvement occurs through the incorporation of assessment data into curriculum planning in a systematic and ongoing process (Figure 2.1). Through assessment of students' educational experiences and outcomes, information is obtained about what educational processes and approaches are successful and which are not. With this information, curriculum planning can proceed from a foundation of knowledge to improve the educational process. An ongoing interaction between assessment and curriculum modification and planning creates the cycle of continuous improvement in an academic program and should influence how students experience college and their learning outcomes.

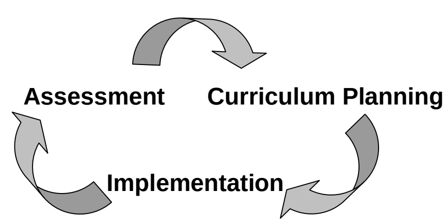

Figure 2.1: Continuous Improvement in Undergraduate Education

Continuous Improvement

Continuous improvement (CI) is an organizational philosophy that "utilizes scientific outcomes measurements, systematic management techniques, and teamwork to achieve the mission of [an] organization" (Freed, Klugman, & Fife, 1994, p. 5). Although a number of different approaches fall under the umbrella of continuous improvement, Freed and her colleagues distill seven common principles:

1. Continuous improvement is mission driven.
2. Continuous improvement recognizes the interdependence of system components.
3. Continuous improvement stresses data-based decision-making.
4. Continuous improvement empowers all participants to participate collaboratively in decision-making.
5. Missions, and thereby processes, are constantly changing.
6. Education and training are necessary to respond to change.
7. Dedicated leadership is critical.

Because these principles of continuous improvement have come to higher education from business, disciplines with high industry contact, such as business and engineering, are often leaders in the continuous improvement movement on campus.

Over the past two decades, continuous improvement in its many forms (e.g., total quality management and continuous quality improvement) has become part of the vocabulary of campus administrators nationwide. In 1993, the American Council on Education reported that seven in ten institutions reported using continuous improvement and that one in ten used it extensively (El-Khawas, 1993). While some authors have argued that these numbers are inflated (Calek, 1995; Marchese, 1997), the higher education practitioners' literature throughout the 1990s focused intensely on the application of continuous improvement principles to meet a variety of institutional goals, bolstering the argument that continuous improvement was being used or at least considered by a large proportion of institutions. By the year 2000, however Birnbaum confidently lumped continuous improvement efforts into a group of "academic management fads" whose time in higher education had come and gone (2000).

Continuous Improvement in EC2000

Fad or not, new continuous improvement initiatives continued to appear. In the world of engineering education at the end of the 1990s, programs seeking ABET accreditation were faced with the EC2000 criterion, which required, among other things, the use of evaluation and assessment for "continuing improvement" of the program (ABET Engineering Accreditation Commission, 1997). In addition to the incorporation of continuous improvement into curriculum planning, EC2000 outlines 11 learning objectives for all engineering programs, regardless of discipline (see Table 2.1), and requires evidence that these objectives are being met. It is not enough for engineering programs to demonstrate what they are teaching; they must also demonstrate what students are learning. The findings of such assessments are then to be incorporated into ongoing curricular improvement. The *Engineering Change* study provides preliminary evidence suggesting that some faculty activities related to EC2000 may have resulted in improved student learning, however no link between continuous improvement efforts in curriculum planning and student learning has yet been explored.

Table 2.1: EC2000 Criterion 3 Learning Outcomes

a. An ability to apply knowledge of mathematics, science, and engineering
b. An ability to design and conduct experiments, as well as to analyze and interpret data
c. An ability to design a system, component, or process to meet desired needs
d. An ability to function on multi-disciplinary teams
e. An ability to identify, formulate, and solve engineering problems
f. An understanding of professional and ethical responsibility
g. An ability to communicate effectively
h. The broad education necessary to understand the impact of engineering solutions in a global and societal context
i. A recognition of the need for, and an ability to engage in life-long learning
j. A knowledge of contemporary issues
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Source: ABET. (1997). *Engineering Criteria 2000.*

Continuous Improvement in Academic Planning

Continuous improvement efforts swept colleges and universities in response to growing criticism of the quality and effectiveness of higher education in the United States. The continuous improvement philosophy offers several advantages over the curriculum planning processes that are currently commonplace in most college and university academic departments. As a number of studies have described, curriculum planning is largely an individual faculty effort directed primarily by content, and failing to use assessment results, such as grades from previous courses and student course evaluations, as a tool for course improvement (Stark & Lattuca, 1997; Stark, Lowther, Bentley, Ryan et al., 1990). In contrast, continuous improvement principles suggest that academic planning should be viewed as a system in which inputs, processes, and outputs each provide opportunities to assess and improve the curriculum (Stark & Lattuca, 1997). For example, the use of customer satisfaction to assess quality is consistent with Stark and Lattuca's emphasis on knowing and understanding the needs of students and other clientele of academic programs (e.g. employers, parents, alumni, governmental agencies, etc.) and using that understanding to improve curricula.

Another facet of continuous improvement that has significant implications for curriculum planning is its focus on human resource development. Continuous improvement organizations do not assume that employees have the necessary tools to apply continuous improvement principles and therefore invest substantially in employee training. In higher education, faculty often lack formal training in curriculum development. Stark and Lattuca (1997) recommend that institutions provide faculty with professional development opportunities for curriculum development and create a culture in which faculty feel that such efforts are valued.

Resistance to Continuous Improvement in Curriculum Planning

Despite the potential for the application of continuous improvement to curriculum planning and its overlap with the planning model advocated by Stark and Lattuca (1997), continuous improvement has met with faculty resistance. Many authors and practitioners point to organizational culture, particularly faculty culture, as a critical aspect in the success or failure of continuous improvement. This resistance or indifference to continuous improvement is often cited as a major obstacle to its implementation in academic programs (American Association for Higher Education, 1994; Salegna & Bantham, 2002; Schwartzman, 1995). One of the most common concerns faculty members express in response to assessment and improvement efforts is the difficulty of measuring many important objectives of higher education (Ewell, 1991b; Rogers, 1988; Terenzini, 2000).

In his review of the assessment movement in higher education, Ewell (1991b) noted that assessment as then practiced focused primarily on estimating students' abilities related to discrete traits. While this approach is useful for measuring basic skills and content knowledge, it is not capable of adequately measuring students' attainment of complex, integrated abilities, such as critical thinking. Two decades into the assessment movement, faculty members are still expressing concerns about the rigidity and limitations of an education focused on documenting measurable objectives (Alexander, 2006).

Faculty members also distrust the corporate jargon associated with continuous improvement, particularly the view of students as customers (American Association for Higher Education, 1994; Schwartzman, 1995; Stark & Lattuca, 1997). The attempted transformation of students into customers is not uniquely a result of continuous improvement initiatives. External pressures to be cost-effective, compete for limited resources (including students), and to demonstrate accountability have contributed to this transformation (Schwartzman, 1995).

Schwartzmann warns that acceptance of this metaphor has great potential to change the process of higher education into one in which "customers can buy immediate satisfaction at the expense of [their] own long-term best interest" (p. 21). Aliff (1998) cites a number of concerns related to treating students as customers, including the fear that students will become passive recipients of education and that faculty will "pander" to students. Aliff expressed the concerns felt by many faculty members when he wrote that:

> [Continuous improvement] has been implemented successfully at several universities. The tables of results, however, consistently omit any comments about the quality of education within and beyond the classroom. Money has been saved, procedures have been streamlined. As for teaching and learning, however, treating students as customers carries mixed blessings. Even if students can be understood as customers in some contexts, they deserve more from educators than immediate gratification (1998, p. 25)

Such concerns are common reasons for faculty resistance to the view of students as customers.

Because the application of continuous improvement to curriculum planning is a relatively recent development, the literature describing faculty resistance is largely based on the perceptions of administrators who have attempted or are attempting to establish continuous improvement efforts on their campuses. While these perceptions are informative, research into faculty perceptions and applications of continuous improvement in curriculum planning is largely lacking. In one of the few studies to consider the perspectives of both faculty and administrators, Lattuca et al. (2006a) reported that program chairs generally believe that "more than half or "almost all" of their faculty support systematic efforts to improve, assessment of student learning, and data-based decision making. The faculty corroborated their chairs' reports, with the majority reporting participation in assessment (88%) and the feeling that this level is about right (67%). That study provided evidence of faculty participation in continuous improvement activities and some evidence for a positive link between some continuous improvement activities and student learning. While the Lattuca et al. study is an exception, continuous improvement efforts are most often implemented by people who believe they will work but fail to evaluate their utility in any meaningful way (Stark & Lattuca, 1997). For this reason, the literature on continuous improvement, like that of assessment, is primarily aimed at garnering new converts rather than analytically exploring the effectiveness of continuous improvement efforts.

Indicators of Continuous Curriculum Improvement

As programs increasingly adopt continuous improvement strategies in academic planning, either through internal initiative or external mandate, the need to test the link between such activities and student learning grows in importance. Further, the tendency of institutions in the face of such mandates to “virtually” adopt continuous improvement practices in order to achieve the “the benefits of being seen as adopting a socially desirable innovation [CI] without the costs of actually implementing it” (Birnbaum & Deshotels, 1995, p. 35), increase the need to identify continuous academic planning activities. Without the ability to identify and measure continuous curriculum planning as practiced by academic programs, it is impossible to test the link between such activities and student learning. Recognizing this need, Briggs, et al. (2003) sought to identify its common characteristics. Based on interviews with department chairs and faculty members in 44 programs, representing a variety of institutional types including traditional and professional fields, they developed four criteria (Table 2.2).

Table 2.2: Criteria for Continuous Planning Departments

1. Continuous and Frequent Curricular Planning Processes
2. Awareness and Responsiveness
3. Participation and Teamwork
4. Use of Evaluation for Adaptive Change

Adapted from Briggs, et al. (2003, p. 367).

Briggs, et al.'s (2003) first criterion, Continuous and Frequent Curricular Planning Processes, reflects the extent to which curriculum planning is an ongoing, systematic process. Briggs, et al. operationalize it with a number of faculty activities and attitudes, including frequency of curricular planning discussions and activities, perceptions of curriculum planning as an ongoing process, and the extent to which department mission guides curriculum planning. Criterion two, Awareness and Responsiveness, reflects the extent to which faculty report that their departments make curricular change proactively rather than reactively, respond to internal and external influences, and develop linkages to other departments or institutions. Criterion three, Participation and Teamwork, reflects the level of faculty collaboration and collective responsibility for curriculum, and criterion four, Use of Evaluation for Adaptive Change, is the extent to which faculty not only collect assessment data from multiple sources, but also use it to make curriculum decisions.

Briggs, et al. concluded that some indicators of their criteria may be more applicable to certain institution and program types than to others, but that overall these criteria and their indicators were useful for placing departments into groupings of high, medium, and low levels of continuous program planning. The authors emphasize the need for further research to test the stability and validity of theses indicators and to determine if there is a link between continuous curriculum planning and improved learning outcomes.

Closing the Loop

Like the assessment literature, the continuous improvement literature is filled with examples of how institutions and programs have applied continuous improvement in their administrative and academic functions. The causal link between application of continuous improvement and improvement, however, is missing. Typically these reports (see, for example, American Association for Higher Education, 1994) indicate that continuous improvement strategies were applied and that some improvement in the area of interest occurred, but they fail to credibly tie these successes to specific continuous improvement efforts. Such reports have a predictable format: 1) a problem is identified, 2) continuous improvement strategies are applied, and 3) improvement is seen. Because the results of continuous improvement are most often reported in the practitioners' literature, causal linkages are often made without the rigorous standards applied to more empirically-based literature.

Another weakness of the continuous improvement literature is that authors seeking to demonstrate the effectiveness of continuous improvement often fail to address the "continuous" part of continuous improvement, focusing instead on improvements. For example, despite ABET's focus on continuous academic improvement, Neff, Scachitti, and Zahraee (2001) observe that engineering technology programs often fail to distinguish between improvement initiatives and the application of continuous improvement.

> A year before an accreditation visit, a natural tendency of engineering technology programs is for one or several individuals to drive the improvement process by compiling a list of potential improvements and then carrying out a few shortly before the accreditation visit. (p. 2)

Birnbaum and Deshotels (1999) suggest that such disconnects may occur when continuous improvement strategies are only superficially adopted. The potential for virtual adoption in the face of external pressure makes it difficult to establish a link between continuous improvement and student experiences and learning outcomes.

Assessment of Student Outcomes

Assessment and Continuous Improvement

The outcomes assessment movement predates but is closely linked to efforts to increase the use of continuous improvement strategies in curriculum review efforts (American Association for Higher Education, 1992; Association of American Colleges, 1992; Astin, 1991; Chaffee & Sheer, 1992; Ewell, 1991a). Assessment of student outcomes, as linked to continuous improvement or as a separate movement, has taken center-stage in the higher education literature over the past twenty-five years. Historically this literature has been largely a practitioner-based literature (see for example, Astin, 1991; Palomba & Banta, 1999) focused on sharing assessment practices. In recent years, however, a growing number of researchers have focused on assessment as a topic meriting scholarly exploration. As Trudy Banta (2002) writes, the scholarship of assessment has emerged as a:

> …systematic inquiry designed to deepen and extend the foundation of knowledge underlying assessment. It involves basing studies on relevant theory and/or practice, gathering evidence, developing a summary of findings, and sharing those findings with the growing community of assessment scholars and practitioners. (p. x)

Despite the growing attention to improving assessment processes and utilizing assessment information for improvement, however, many faculty continue to rely on traditional methods of assessment which rely primarily on the assignment of grades and fail to apply the findings from such assessments in the curriculum planning processes.

Outcomes-based Assessment

The assessment movement in recent years can be characterized largely as a transition from input-based models in which course content and program resources were the focus, to output-based models in which student abilities to apply knowledge and demonstrate related skills are the primary criteria (Palomba & Banta, 1999). Outcomes assessment requires faculty to define and communicate course and curriculum objectives so that learners know what is expected. Faculty then base assessments on students' abilities as measured against the criteria (i.e., criterion referencing) rather than against the performance of other students (i.e., norm referencing) (Boughey, n. d.). With clearly established criteria, faculty are then in a better position to provide students with formative feedback.

The Assessment Movement

Outcomes assessment is not a new "fad" in higher education (Hutchings & Marchese, 1990). In 19th century American colleges, the completion of coursework was not sufficient for the awarding of a degree. Seniors were also required to demonstrate publicly their knowledge before a group of outside assessors who were often clergy members and the future professional peers of the graduates. This practice was lost as the American college evolved into the American university. As colleges expanded and faculty increasingly became members of a discipline first and teachers secondarily, the practice of comprehensive senior exams was replaced with credit-based degrees. As Hutchings and Marchese (1990) write, "In losing that practice, we lost as well a tradition of asking questions about our graduates' competence and about the cumulative effects of our teaching and curricula" (p. 15).

Today, however, university faculty and administrators are again trying to find ways to assess and document student learning. As noted previously, increased public scrutiny and mandates for accountability have fueled the assessment movement. In the mid-eighties, critical reports from the National Institute of Education (Study Group on the Conditions of Excellence in American Higher Education, 1984) and the Association of American Colleges (1985) argued that assessment was a key factor in improving learning and the quality of our higher education system.

By the mid-1980s four out of five states were promoting or requiring assessment and regional accrediting bodies were required to mandate outcomes assessment as a condition for accreditation (Hutchings & Marchese, 1990). Although skeptics still remain, many in higher education have accepted assessment as the necessary price of doing business in an era of tight budgets and institutional consolidation. In addition, faculty cultures are beginning to shift as some recognize the value of assessment in improving learning and embrace its philosophy (Hutchings & Marchese, 1990; Palomba & Banta, 1999).

Creating a Culture of Assessment

While faculty culture encompasses a wide array of values, beliefs, and behaviors and their expression, in the context of this study, faculty culture is relevant to the extent that it influences faculty attitudes towards, and participation in, continuous improvement activities. Tichy (1983) argues that because of its pervasive influence on organizational functioning, culture is an important factor in determining organizational effectiveness. Similarly, Braxton, Eimers, and Bayer (1996) maintain that faculty teaching norms (that is, shared beliefs about appropriate behavior) may be important factors in the receptiveness of faculty to undergraduate education reform efforts. Of note, Braxton, et al. found a lack of normative support for improvement of teaching across a variety of disciplines at both Research-I and Comprehensive Universities and Colleges II ,[4] the institution types that house most engineering programs. While faculty culture is recognized as an important aspect of both curriculum reform and organizational effectiveness, no empirical studies have explored the relationship between faculty attitudes and behaviors toward continuous improvement, including efforts to improve teaching, and student learning, a key measure of academic effectiveness.

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[4] In the 1986 Carnegie Classification system used in this study, Research I institutions gave high priority to research; Comprehensive Universities and Colleges offered graduate education through the masters degree and awarded more than half of their bachelor’s degrees in occupational or professional fields.

Tener (1999) described the interaction between faculty culture and outcomes assessment in engineering as one of conflict and congruence. Because outcomes assessment is a critical part of continuous improvement in academic programs as described in the EC2000 criteria, resistance to this type of assessment is directly related to resistance to continuous improvement. Tener suggests that there are eight characteristics of the engineering faculty culture that conflict with the requirements of an outcomes assessment program: 1) faculty resist change, 2) faculty are individualistic, 3) faculty rewards are inconsistent with outcomes assessment, 4) faculty do not always respect outside opinion, 5) faculty resist identifying students as "customers" and seeking "customer satisfaction," 6) faculty prefer knowledge-creating endeavors to process-focused efforts, and 7) top-down changes are often ineffective with faculty.

Although the engineering faculty culture can create obstacles for continuous improvement activities, Tener (1999) also recognizes that certain characteristics of the culture can facilitate such activities. These include 1) the desire of faculty to improve and document their work outcomes, 2) the ability of faculty to enact change, 3) the perception that strategic planning has merit, and 4) the responsiveness of faculty to industry feedback. While Tener's analysis provides a helpful insider's view into engineering faculty culture, it may be more applicable to large research universities than to smaller programs. Further, his analysis is speculative rather than research-based.

Because assessment of student learning, as well as course and curriculum development, are primarily a faculty activity, any continuous improvement effort depends on faculty support for successful implementation (Salegna & Bantham, 2002). In fact, Tener (1999) states that, "The greatest challenge to developing an effective outcomes assessment system is the institutional culture of the faculty" (p. 65). Faculty, however, are often reluctant to embrace continuous improvement, which many perceive as conflicting with traditional faculty values. ABET and other accreditors hope that changing accreditation standards will stimulate changes in faculty culture (Prados et al., 2005) and initial evidence from the *Engineering Change* study suggests that this may be the case (Lattuca, Terenzini, & Volkwein, 2006b).

Research Linking Assessment with Outcomes

While the literature is replete with suggestions for creating a culture of assessment, studies of the effectiveness of such efforts are often lacking or are based on the experience of single program or institution. For example, Hutchings (1996) promotes the use of "teaching circles" in which faculty meet regularly to discuss incorporating the results of assessment into teaching and learning activities, but provides little hard evidence verify the effectiveness of such efforts in promoting student learning. Likewise, Magruder, McManis, and Young (1997) use the experiences of Truman State University to make the case for utilizing assessment for program improvement and cite such results as increased student-faculty interaction, greater expectations for student achievement, and greater student engagement, but provide no empirical evidence to support these outcomes or to link these outcomes to assessment.

Hutchings and Marchese (1990) found that assessment can indeed drive change. For example, at the University of Tennessee at Knoxville (UTK), student survey data revealed student dissatisfaction with teaching assistants (TAs). As a result, the university implemented a TA training program and saw a marked increase in student satisfaction with TAs. Similarly, student survey data indicating low levels of student-faculty interaction stimulated many academic program to increase opportunities for interaction and subsequently the percentage of students reporting that they don't know any "faculty member well enough to ask for a recommendation" dropped from 47 percent in 1983 to 27 percent in 1989. A number of changes prompted by student reports of their first-year experience led to changes in first-year programs. First-year to sophomore retention rate at UTK increased from 62 to 71 percent.

In 1978, Ohio State University made a commitment to increase its use of assessment and to use the results to fuel substantive change. As a result of an assessment-based review of the general education program, a new three-tier general education program was implemented. Using the American College Testing (ACT) College Outcome Measures Program (COMP) and controlling for ability, Ohio State documented that seniors who took the COMP prior to implementation of the new general education program scored lower than those who took it during and after the new requirements (Williford & Moden, 1993). Similarly, during the 1980s, Ohio State reported increases in first-year student retention and in student satisfaction with faculty and staff interactions following the implementation of changes to retention, academic advising, and academic support programs stimulated by the data from student and alumni assessment.

Walleri and Seybert (1993) describe the assessment efforts and related improvements in student outcomes at several community colleges. Faculty at Seattle Central Community College for example, observed that only about one-half of their intermediate algebra students from 1987 to 1990 had received a C grade or better. Using assessment data, the faculty determined that student underperformance was most likely due to the curricular and pedagogical approaches being employed and as a result, implemented significant changes focused on applying algebra to real-world situations. Following changes to the course, the percentage of students receiving a C or better increased from 53 to 71 percent.

RiCharde, Olneyh, and Erwin (1993) explore the ways in which assessment efforts have had meaningful effects on students at Virginia Military Institute (VMI). VMI used a number of affective and cognitive development instruments to identify the types of students most likely to drop out due to academic- and nonacademic-related stress during the first-year. Based on these results, VMI implemented programs to establish realistic expectations in students for the first-year, to prepare parents to provide appropriate family support, and to provide academic support.

After implementing these programs, VMI reported a steady decrease in student attrition and higher first-year grade point averages (GPAs).

Unfortunately, in each of these examples, we cannot link these changes to assessment with confidence because the authors provide little in the way of supporting evidence. Improvements in these areas, while impressive, may be the result of a variety of factors in addition to or in lieu of the changes prompted by assessment results. What these single-institution examples do provide however, is the impetus for further study of the effects of outcomes assessment using standardized measures across institutions and applying sophisticated analyses to control for alternate explanations.

In addition to using assessment to identify problems and develop appropriate responses, proponents argue that assessment should be used as a means to improve institutional quality (American Association for Higher Education, 1992; Palomba & Banta, 1999). As Peterson and Augustine (2000) suggest, institutions using assessment as a component of a quality improvement processes should use the data from assessment to make academic decisions. In order to discover whether or not institutions actually use assessment data in academic decision-making, Peterson and Augustine surveyed all 2,524 US institutions of postsecondary education (excluding specialized and proprietary institutions) and received responses from more than half. They concluded that student assessment had only a "marginal" influence on academic decision making nationwide. Because their focus was on institutional improvement, survey respondents (chief academic officers or their designees) reported on the "essence of assessment" for their entire campus. Consequently, the study could not capture any disciplinary differences that may exist among different academic programs or reveal the perspectives of faculty and administrators at different levels within the institutions.

In the *Engineering Change* study Lattuca et al. (2006a) asked both engineering faculty and program chairs about the use of assessment in their programs. Despite some variation among engineering disciplines, program chairs on the whole reported that the majority of their faculty support assessment of student learning (70%), data-based decision making (64%), and systematic efforts to improve (73%). Faculty reports corroborated the chairs' assessments of their participation in assessment, with 90 percent reporting at least some personal effort. When asked about the extent to which assessment influenced curriculum planning however, faculty were more pessimistic than chairs. Seventeen percent of program chairs reported that curriculum decisions were typically based on opinions rather than data, but more than twice that number (40%) of faculty reported that such was the case. These findings suggest that assessment as a component of curriculum planning may not be infiltrating faculty culture to the extent that accreditors may wish.

Curriculum Improvement and Planning

Planning

Course and curriculum planning are key faculty responsibilities in most American colleges and universities,[5] These two tasks have much in common, but course planning is primarily an individual affair (Stark, 2000), while curriculum planning requires cooperation among diverse faculty members (Briggs et al., 2003). In the past decade, we have learned a great deal about how college faculty approach course and curriculum planning, For instance, we know that faculty spend relatively little time in systematic curriculum planning despite the fact that the academic program is their primary interface with students (Stark & Lattuca, 1997). Faculty that apply continuous improvement principles, in contrast, would be expected to consider curriculum planning an ongoing process in which they considered the needs of their students and the needs of

[5] Curriculum planning in community and for-profit institutions may vary from this model; however the focus of this project is traditional, four-year, not-for-profit institutions.

the curriculum (e.g., how their course affects and interacts with other courses in the major). Such faculty would use assessment data to drive curriculum planning, rather than making changes (or not) based on instinct and anecdotal evidence.

An outcomes-based approach to continuous improvement also requires that faculty predetermine specific curricular goals and identify ways to measure achievement of these goals (Haworth & Conrad, 1997; Seymour, 1992). When asked about their goals for introductory courses, faculty in Stark's (2000) study overwhelmingly supported broad goals for students including effective thinking, improving the world, and clarifying values. Nevertheless, when interviewed, more than half of the goals provided by the 2105 participating faculty focused on conveying skills, concepts, and knowledge in the field. Stark also found that only small numbers of faculty begin the planning process for their introductory courses by thinking about student needs, activities to promote learning, course objectives based on external standards, or student evaluations and grades from previous courses. Despite the suggestions of faculty that they approach advanced courses differently, Stark found very few differences in the way faculty planned for introductory and advanced courses.

While faculty dedicate little time to planning prior to teaching an existing course, they do report making continuous adjustments to the curriculum over the course of a class. Stark (2000) refers to this most common type of course planning as "routine maintenance" and contrasts it with "routine review," a systematic procedure of course examination, "major revision," and "planning a new course." Major revisions of a course occur infrequently and most often in response to a perceived problem (Stark & Lattuca, 1997). In this respect, faculty course planning may resemble continuous improvement approaches, at least at the course-level, if not at the program-level.

The resemblance between routine maintenance and continuous improvement practices breaks down further when compared to data-based decision making. Less than half of the faculty surveyed by Stark, et al. (1990), said that they used the results of student ratings of their teaching to make course adjustments and only 45 percent said that they look at examinations from previous courses. Further, less than one percent of all faculty respondents in that study reviewed previous student evaluations or course examinations as a first step in course planning. The practice of ongoing course adjustment is congruent with the principles of continuous improvement, and suggests that faculty culture may be amenable to continuous improvement. However, the lack of intentional curriculum planning and reactionary rather than proactive approach to curricular change is inconsistent with a philosophy of ongoing data-based decision making.

Influences on Curriculum Planning

Faculty approaches to course and curriculum planning are most strongly influenced by their academic field (Braxton & Hargens, 1996; Stark, 2000; Stark, Lowther, Bentley, & Martens, 1990). This is not surprising given that academic fields provide the basis for course content, external standards and norms (via professional societies and accrediting bodies), as well as faculty members' epistemological frameworks (Stark & Lattuca, 1997). Stark, Lowther, Bently, and Martens (1990) concluded that different factors affect the course planning activities of faculty in different disciplines. For example, Stark et al. found that teachers of introductory courses in literature, history, sociology, fine arts, and psychology tended to focus more on student needs for growth than did math teachers. Similarly, Donald (2002) identified variations in the kinds of thinking skills that faculty in different academic fields stressed in their courses. Although academic field is the most influential factor in faculty course planning, Stark, Lowther, Bentley, and Martens (1990) found that planning was also affected by local conditions such as student goals, college mission, facilities, and external influences. Such "contextual influences" are outside of a faculty member's immediate control (Stark & Lattuca, 1997).

Based on their series of course planning studies, Stark and her colleagues developed the "contextual filters" model (Stark, 2000; Stark & Lattuca, 1997; Stark, Lowther, Bentley, Ryan et al., 1990). This model is organized around the idea that teachers' disciplinary views and assumptions underlie and affect their planning process. The model is in three parts:

> Content, (which encompasses faculty beliefs, purposes, and disciplines as the key factors in course planning), context (which influences and modifies the content and of which student characteristics are most prominent), and form, which includes the final decision that teachers make based on content and context. (Stark, 2000, p. 430)

In addition to student characteristics, contextual influences may include: student goals, external influences, program goals, college goals, pragmatic factors, pedagogical literature, campus resources related to teaching, and facilities. Course planning is delineated as selecting and arranging content, establishing goals and objectives, and selecting learning activities. This model has been very influential in recent conceptualizations of faculty course planning, including the "academic plan" model of Stark and Lattuca (1997). While the contextual filters model focuses on how planning affects course form, the ideas it presents are useful in exploring influences on faculty planning processes generally.

The inclusion of external influences in the contextual filters model illustrates the vector by which continuous improvement may take be established in curriculum planning processes. Faculty, particularly those in professional disciplines (Lattuca, Strauss, & Sukhbaatar, 2004; Siller & Johnson, 2004), may respond to external pressures such as those brought to bear by accreditors, and may incorporate a continuous improvement curriculum planning model in such situations. Faculty culture and institutional culture, however, may trump such pressures. The failure of faculty to invest heavily in curriculum planning documented by Stark and her colleagues (Stark, 2000; Stark & Lattuca, 1997; Stark, Lowther, Bentley, Ryan et al., 1990; Stark, Lowther, Ryan, & Genthon, 1988) may be due to an academic culture that has largely attempted to follow the standards set by the most prestigious research universities, where research is perceived to outrank all other pursuits (Altbach, 2005; Schuster & Finkelstein, 2006). Engineering programs have not been immune to this transition in faculty orientation and, like other disciplines, have come under fire for neglecting teaching (Prados, 1998). Lattuca et al. (2006a), found that since the implementation of EC2000, engineering faculty did in fact report increased activities suggestive of a continuous improvement approach to curriculum planning, but further research is needed to explore the extent of these activities within engineering education.

Limitations of the Curriculum Planning Literature

Prior to the late 1980s relatively little research examined how college faculty plan their courses and curricula. During the 1990s a number of empirical studies, including much of the research described here, emerged from the National Center for Research to Improve Postsecondary Teaching and Learning [NCRIPTAL]. The NCRIPTAL data contributed greatly to our understanding of faculty course planning processes and the factors that influence them. However this data has a number of limitations that are particularly cogent to this study. Because NCRIPTAL's funding is dedicated primarily to the study of undergraduate education in teaching institutions, research universities and their faculty are greatly underrepresented. These institutions, however, are the greatest producers of science and engineering graduates (National Science Board, 2006). Further, engineering is not included among the academic fields represented by the extensive work of Stark and her colleagues.

While undoubtedly many of the practices described in the NCRIPTAL studies may apply to engineering faculty, the course and curriculum planning of this group cannot be determined from the existing literature. Since it was recognized as a field in the mid-1800s, engineering has developed a unique culture (Donald, 1991a, as cited in Hativa, 1995). As an academic field with a strong vocational and applied focus, engineering also may be more responsive to external influences, such as employers and accreditation, than the arts and sciences (Lattuca et al., 2004; Siller & Johnson, 2004). The higher education literature, however, has largely marginalized professional education as an area of research, failing to address its unique characteristics or ignoring it completely (Rhoades, 1991). When there are exceptions to this oversight (see Braxton & Hargens, 1996; Stark, 1998; Stark, Lowther, Bentley, & Martens, 1990), the focus has primarily been on intellectual influences of the discipline rather than on organizational and cultural aspects of the field.

In their study of faculty perceptions of disciplinary environments, Stark, Lowther, & Hagerty (1987) concluded that faculty in engineering, business, architecture, and other professional disciplines perceive their programs as functioning in unique environments that are strongly influenced by external forces. Although an overrepresentation of deans and program chairs (who may potentially have been more sensitive to external forces) and a nonrandom sample of faculty limits the generalizability of the findings of this study, it nonetheless lends some empirical support to the commonly held perception that faculty in professional fields function under different influences than faculty in less vocationally-oriented fields. These findings suggest that engineering programs might be particularly responsive to accreditation pressures to incorporate continuous improvement into curriculum planning and for this reason they provide a promising starting point for investigating the assumption that good planning leads to good learning.

As described, the curriculum planning literature has focused primarily on documenting faculty course planning processes and on identifying the influences responsible for observed differences among these processes. While providing critical information to those seeking to improve course planning, the warrant for such efforts is based on the untested assumption that course planning is linked to student learning. None of these studies empirically tie planning processes to any type of student outcome. Further, this literature focuses almost exclusively on the efforts of individual faculty, failing to explore the cooperative efforts required to create a cohesive and effective college curriculum (for an exception, see Briggs et al., 2003).

Continuous Improvement in Curriculum Planning

The curriculum planning literature is based on the assumption that good curriculum planning practices will ultimately improve learning. While a number of studies have explored faculty curriculum planning none have established this empirical link. Lattuca, et al. (2006a) recently completed the first study that sought to make the connection between faculty and program activities and student learning. The *Engineering Change* study is based on a nationally-representative sample of engineering programs and applies a conceptual framework that seeks to describe the complex array of interactions between students, their college environment, and their learning outcomes.

In the *Engineering Change* study Lattuca, et al. found that, controlling for student and institutional characteristics, program-level assessment activities geared toward improvement significantly and positively affected students' in-class experiences (the amount of instructor interaction and feedback as well as and instructor clarity and organization) and out-of-class experiences (participation in internships/cooperative education, participation in design competitions, and involvement in a student chapter of their professional society). They also found that faculty participation in professional development geared toward improving instruction (such as attending a workshop on teaching aggregated at the program level), significantly increased students' reports of the frequency of instructor interaction and feedback.

Faculty participation in projects to improve undergraduate education also had significant, if weak, direct effects on some student learning outcomes (experimental skills, math and science skills, engineering skills, design and problem-solving skills, and life-long learning skills). These findings largely supported previous work indicating that student experiences have the most profound influences on learning (Pascarella & Terenzini, 1991, 2005). Lattuca, et al. concluded, however, that it is likely that the effects of faculty activities to improve their programs and instruction, including those related to assessment and professional development, on student learning outcomes are indirect, rather than direct. Faculty continuous improvement efforts primarily occur "behind the scenes" and their influences on students may be subtle. For this reason and based on the conclusions of Lattuca, et al., the nature of the relationship between continuous improvement and student experiences and outcomes may be more accurately reflected when continuous improvement is considered as a potential moderator or indirect influence on the relationship between student experiences and student learning, rather than as a direct influence. The regression analyses used in the Lattuca et al. study however were insufficient to explore this hypothesis.

The Conceptual Framework

The conceptual framework for this study posits that students' pre-college characteristics interact with college and university environments to affect educational experiences and ultimately, student outcomes. This framework is based on the student outcome models created for the *Engineering Change* Study by Lattuca, et al. (2006) and further developed by Terenzini and Reason (2005), which in turn extend the sociologically- and social psychologically-based theories of college effects proposed by Astin (1993), Tinto (1993), and Pascarella (1985; Terenzini & Reason, 2005). By incorporating student pre-college characteristics, organizational environment, student experiences and student outcomes, these frameworks address a void in the literature by describing the complex and interconnected array of variables and settings which influence student learning (Pascarella & Terenzini, 1991, 2005; Terenzini & Reason, 2005). Further, these models suggest causal relationships that lend themselves to further empirical exploration.

Lattuca et. al.'s framework for the *Engineering Change* study was developed to explain the impacts EC2000 on engineering programs and students, and looked broadly at organizational context and student experiences as interacting components which affect student outcomes. That framework hypothesized that EC20000, which includes a requirement that programs practice assessment and continuous improvement, continually stimulates program changes (Figure 2.2). The closely related framework proposed by Terenzini and Reason (2005) takes the same basic form as Lattuca et al.'s model but was developed to explain the impacts of college on students in their first year and looks broadly at organizational context and peer environment, including student experiences, as interacting components which affect student outcomes. Despite the focus on first-year students, the authors provide a convincing argument in support of its broader application to the entire college experience of students.

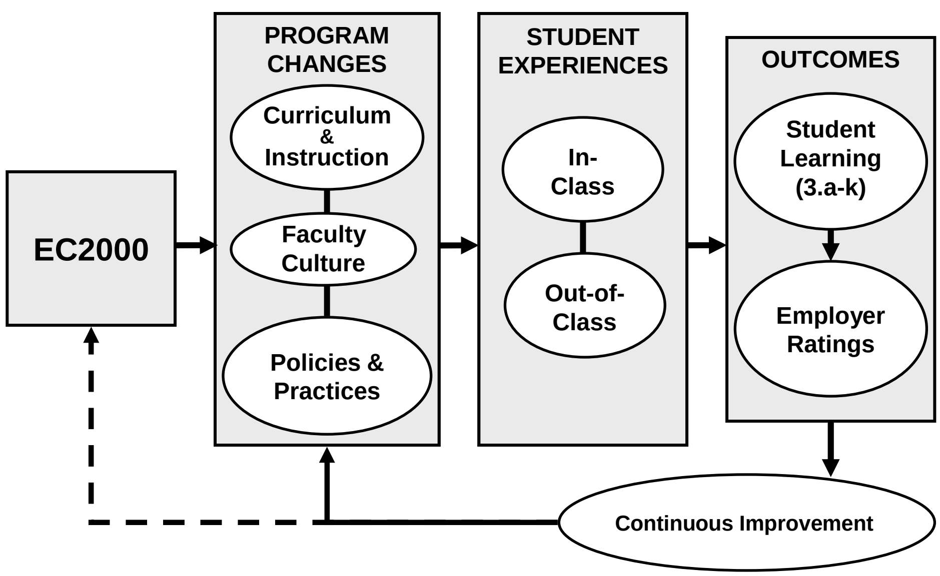

Figure 2.2: Conceptual Framework for the Engineering Change Study [6]

[6] Source: Lattuca, Terenzini, and Volkwein (2006b), p. 2. Copyright © 2006 ABET, Inc.

In order to explore the effect of faculty continuous improvement efforts on student outcomes, I use these two closely-related models as a foundation. In adapting these frameworks to focus specifically on the impact of continuous improvement, I define faculty culture as support for and activities related to assessment and continuous improvement, and delineate student learning as the outcome of interest, while keeping the original frameworks' broader conception of the student experience (see Figure 2.3). This study contributes to the broader model by testing one critical assumption of the model – the connection between continuous curriculum planning, as a dimension of faculty culture, and student learning.

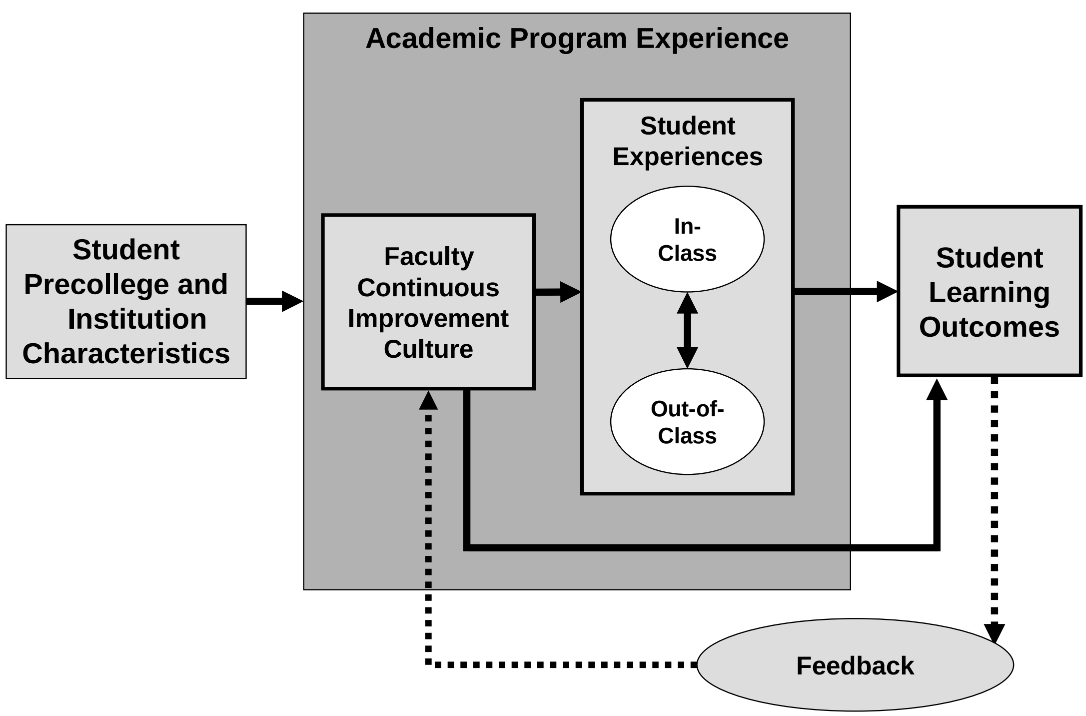

Figure 2.3: The Impact of Continuous Improvement on Student Learning

The framework for this study may be considered a “college impact model” rather than a “developmental theory” because it examines environmental effects and interindividual influences on student change (Pascarella & Terenzini, 1991, 2005; Terenzini & Reason, 2005). Developmental theories, in contrast, address intraindividual changes or “the nature, structure, and processes of individual human growth” (Pascarella & Terenzini, 2005, p. 18). College impact models describe a number of external variables presumed to influence student outcomes. Common model variables include a variety of student characteristics, institutional traits, student experiences, and/or environmental influences (Terenzini & Reason, 2005).

Chapter 3

METHODS

Operationalizing the Conceptual Framework

The conceptual framework is based on the assumption that if continuous improvement activities, as applied to engineering program curricula, have a positive effect on student learning, then faculty activities related to continuous improvement are most likely to affect student learning indirectly through their effect on student experiences. Using hierarchical linear modeling to test the possibility of a direct effect and path modeling to explore the indirect influences, this investigation will test these hypothesized linkages.

In order to evaluate the links between the continuous improvement culture of faculty and student outcomes these latent[7] variables must be operationalized in a logical and measurable fashion. Following the conceptual framework and grounded in the higher education literature, Lattuca et al. (2006a) developed an analytical model to evaluate the linkages between EC2000 and student learning outcomes. In order to apply the *Engineering Change* data to the more focused question of the link between continuous improvement activities and student outcomes, the analytical framework is modified herein to focus on the activities of individual faculty and engineering programs related to continuous improvement (Figure 3.1).

[7] Latent variables are constructs that cannot be directly observed and measured. They are defined in terms of behaviors that represent the construct.

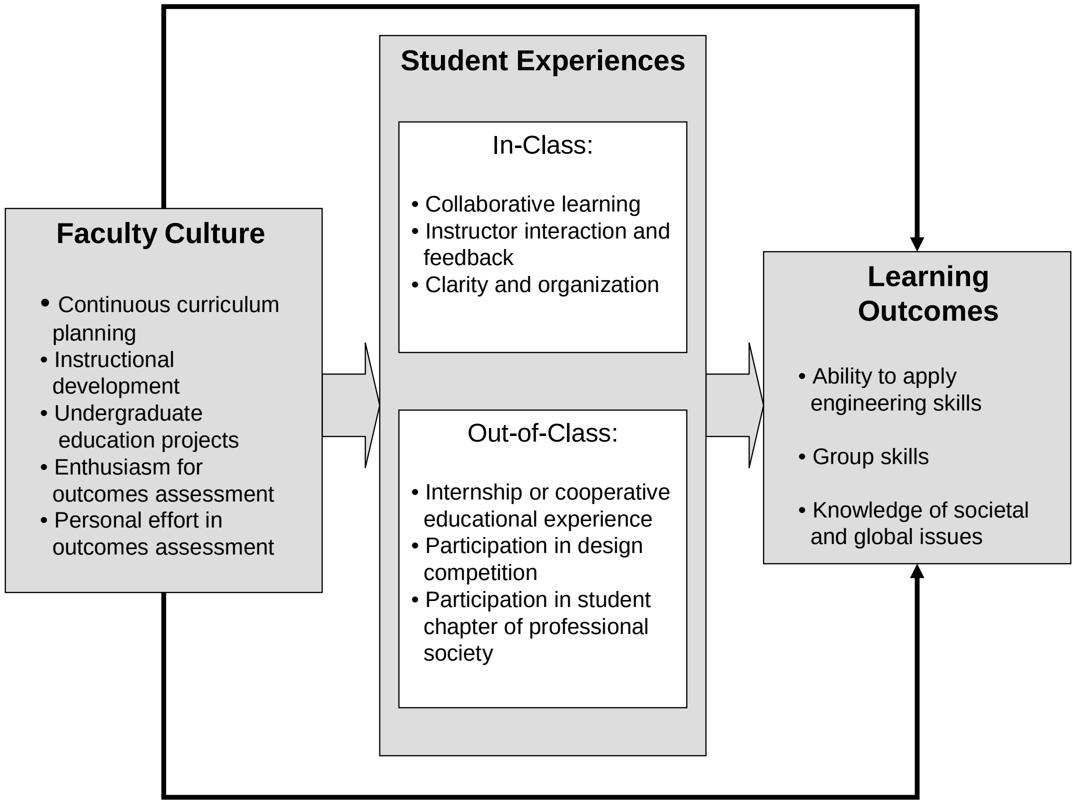

Figure 3.1: Analytical Model Linking Faculty Culture to Three Learning Outcomes of Interest to Engineering Faculty and Employers

Design, Population, and Sample

This study employs an *ex post facto* cross-sectional survey design, utilizing data collected for the *Engineering Change* study in 2004 (Lattuca et al., 2006a).[8] The *Engineering Change* study was designed to provide a nationally representative sample of ABET-accredited programs in the five engineering fields (civil, chemical, electrical, industrial, and mechanical) that produce approximately 75 percent of baccalaureate graduates in any given year and two additional fields (aerospace and computer) with particularly close industry ties. The target population for the study

[8] Unless otherwise indicated, all information on the study design, population, sample, data collection, and variables for the *Engineering Change* study is drawn from Lattuca, Terenzini, Volkwein et al. (2006).

consisted of 1,024 engineering programs in 244 U.S. colleges and universities. Because the *Engineering Change* study collected data in order to investigate the effect of EC2000's implementation in 1997, the target population was limited to engineering programs that were ABET-accredited since 1990.

The sampling population within the target was chosen to provide a nationally representative sample of ABET-accredited programs and consisted of 40 institutions, in which all engineering program chairs, faculty, and 1994[9] and 2004 seniors expect to graduate in 2004 in the relevant disciplines received a survey relevant to their experiences (Appendix A). The research team used a 7x3x2 disproportionate stratified random sampling design to select a nationally representative sampling population of engineering programs using three strata:

- seven engineering disciplines (aerospace, chemical, civil, computer, electrical, industrial, and mechanical);
- three categories (early, on-time, late) describing EC2000 adoption status (institutions that underwent an accreditation review under the EC2000 criteria prior to being required to do so, institutions that underwent review when required, and institutions that requested a received extra time to prepare for an EC2000 review); and
- two categories (yes or no) representing participation in an NSF Engineering Education Program Coalition membership (participants in these coalitions are thought to be leaders in engineering education reform).

Smaller disciplines (aerospace and computer engineering) were deliberately over-sampled, as were Historically Black Colleges and Universities and Hispanic-Serving Institutions, to ensure adequate representation of these disciplines and of students of color. Using these strata, the sample population of programs closely resembled the target population in number of

[9] 1994 graduates not included in this analysis because their college experience pre-dates the implementation of EC2000 and the subsequent focus on continuous curriculum improvement in engineering programs.

undergraduate degrees awarded by discipline, number of faculty within each discipline, percentage of undergraduate degrees awarded based on institutional control (public or private), and in program size.

Data Collection Procedures

In collaboration with engineering faculty at Penn State University, engineering employers, and a National Advisory Board composed of engineering educators, engineering deans, industry representatives, and assessment experts, researchers developed, pilot tested, and refined survey instruments for faculty and students. Student surveys provided demographic information, ratings of undergraduate engineering experiences and learning outcomes, and information on plans after graduation. Faculty surveys provided demographic information, information about courses and curriculum planning, and ratings of student abilities. For the full surveys, refer to http://www.ed.psu.edu/cshe/abet/instruments.html or Lattuca, Terenzini, and Volkwein (2006a).

Data collection occurred in 2004, using participants recruited through standard and electronic mail. Students received a $2.00 incentive to encourage participation. Because research suggests that some survey takers still prefer paper and pencil surveys to web-based surveys, both student and faculty participants were given the opportunity to choose between a paper- and a web-based survey in order to maximize response rates (Carini, Hayek, Kuh, Kennedy, & Ouimet, 2003; Porter, 2004).

Survey instruments and procedures were reviewed for compliance with professional and ethical standards related to human-subjects research and approved by the Pennsylvania State University Office of Research Protection. The Survey Research Center (SRC) of the Pennsylvania State University sent survey packets to students at 20 of the survey institutions including a description of their rights as human subjects, a paper survey, a return envelope, and directions for accessing the web version of the survey (if that format was preferred). Students at the remaining 20 institutions received electronic invitations only. Follow-up contacts included reminder postcards and a complete follow-up (similar to the original invitation to participate). The SRC also collected the survey data and provided it to the research team in an electronic database without personally identifying information in order to ensure participants' confidentiality.

Faculty participants were recruited with the help of their college deans, who emailed faculty requesting their participation. The initial SRC hardcopy mailing was similar to that sent to students but also included the endorsement of the primary professional engineering societies. The SRC used the same follow-up strategies as with the student sample, with the addition of a third reminder in email form after the second hardcopy mailing. The resulting sample included survey responses from 1,243 faculty members (42% response rate), and 4,330 graduates of 2004 (34%; hereafter referred to as students), representing bachelor's, masters, and research colleges and universities.

Variables

The *Engineering Change* database contains a number of variables relevant to this study. The faculty data include variables that will be used to operationalize engineering programs' faculty culture as it relates to continuous improvement culture. The student data include multiple variables measuring student experiences and student learning. In addition, several control variables are used in the analysis in order eliminate possible alternate hypotheses.

Control Variables

The *institutional control variables* are size and wealth. These institutional characteristics influence institutional culture and resources, thereby potentially influencing students' learning outcomes. Institution size is engineering enrollment and wealth is the average faculty salary. Both values were drawn from the Integrated Postsecondary Data System (National Center for Educational Statistics, 2001). The *student control variable*s are gender, underrepresented minority status, parents' education, family income, high school grade point average, and SAT score. Each of these variables represent potential influences on student learning that are not attributable to academic programs. Including these variables in the analyses means that findings cannot be attributed to these factors. Although more detailed student race/ethnicity categories were available,[10] the small numbers of student respondents in some categories combined with the lack of statistical significance of these variables in preliminary regression analyses, led to the collapse of these categories into a dichotomous minority variable. See Appendix B for detailed information on each variable.

Continuous Improvement Variables

Faculty culture relating to continuous improvement is operationalized using a number of measures reported in the faculty survey. Faculty in the *Engineering Change* survey reported their levels of enthusiasm for and participation in outcomes assessment. Because outcomes assessment is key factor in continuous improvement, these metrics may be used to determine both faculty attitudes and commitment to continuous improvement in their own programs. Further, faculty engagement in continuous curriculum planning is operationalized through a number of survey questions based on the "continuous planning" faculty activities identified by Briggs et al. (2003):

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[10] White, Black/African American, Hispanic/Latino, Asian, American Indian/Alaskan Native, Hawaiian or Pacific Islander, and other.

continuous and frequent curricular planning, awareness and responsiveness, participation and teamwork, and use of evaluation for adaptive change.

Continuous improvement, as an organizational philosophy, also stresses the need for ongoing education and training in order to respond to ever-changing missions and processes (Freed et al., 1994). Subsequently, another expression of a continuous improvement faculty culture is the participation of faculty in professional development activities related to instructional development and projects to improve undergraduate education. Because engineering faculty often lack training in curriculum development (Wankat et al., 2002), participation in professional development activities that focus on assessment, course development, and course improvement may be an expression of commitment to continuous improvement.

The continuous improvement variables used in the analyses include three scales developed for the *Engineering Change* study and four individual survey items of interest. Factor analysis using Varimax rotation yielded three relevant scales from the faculty data: continuous curriculum planning (.82),[11] instructional development (.73) and projects to improve undergraduate education (.64) (see Appendix B for scale content). In addition to the scales, two individual survey items are of interest in this model: faculty members self-reported enthusiasm for and participation in outcomes assessment.

Student Experience Variables

While student learning may be directly influenced by faculty culture, previous investigations of student outcomes, including the *Engineering Change* study, indicate that student experiences have the strongest and most significant effects on student outcomes (Lattuca et al.,

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[11] Cronbach's alpha ranges from .00 to 1.00 and reflects the reliability of a scale by analyzing its internal consistency (i.e., whether respondents answering one item high or low tend to answer other items in the scale higher or low in a consistent fashion). Psychometricians typically consider any scale with an alpha of .70 or higher to be acceptable, although scales with alphas in the .5 or .6 ranges are occasionally used.

2006a; Pascarella & Terenzini, 1991, 2005). Factor analysis of the student data yielded three classroom experience scales of interest: collaborative learning (scale alpha=.90), instructor interaction and feedback (.87), and instructor clarity and organization (.82). In addition to these scale variables, individual items related to student participation in internships and cooperative education, design competitions, and student chapters of professional societies were included as predictors in the models.

Students' in-class experiences have been linked to a variety of student outcomes including attitudes, values, beliefs, moral development, behavior, knowledge, and cognitive development (Astin, 1993; Pascarella & Terenzini, 1991, 2005). While it is not possible to investigate the effects of every aspect of students' in-class experiences on the outcomes of interest, previous work with engineering students has identified a number of specific experiences that significantly affected student outcomes. For example, teacher clarity, interaction, and feedback have been significantly and positively related to student achievement, gains in design and professional skills (Bjorklund, Parente, & Sathianathan, 2004; Kulik & Kulik, 1979; Lattuca et al., 2006a). Collaborative learning among students has also been linked to a number of outcomes, including achievement, positive attitudes toward a subject area, and peer group cohesion (Johnson, Johnson, & Smith, 1991).

In their study of engineering students, Cabrera, Colbeck, and Terenzini (2001) explored the effects of instructor clarity, instructor interaction and feedback, and collaborative learning in the classroom on group skills, problem solving skills, and occupational awareness. Controlling for a variety of student characteristics, they found that these instructional practices did significantly affect student gains on the outcomes of interest. Based on the findings of the *Engineering Change* study and previous studies that instructor clarity, instructor interaction and feedback, and collaborative learning can significantly affect student learning, these instructional practices were chosen to operationalize the in-class experience of the study's engineering students.

While faculty and administrators have the greatest control over students' in-class experiences, a growing body of evidence points to the importance of out-of-class activities on student outcomes (Pascarella & Terenzini, 1991, 2005). In engineering programs, a number of important out of-class activities contribute to students engineering education. Internships or cooperative education experiences, for example, were recommended or required by 80 percent of engineering programs in the *Engineering Change* study. These work experiences may help students test their "fit" in engineering and help students form relationships with engineering firms (Parsons, Caylor, & Simmons, 2005). In addition, they can contribute to student learning (Lattuca et al., 2006a), and positively affect student grade point averages and starting salaries (Blair, Millea, & Hammer, 2004; Parsons et al., 2005).

Like internships, participation in engineering design competition gives students the opportunity to apply the skills they've learned in the classroom. Design competitions typically require student to work collaboratively to meet the needs of a "client." Student teams must operate under time and resource constraints, while competing with other "firms." Student teams typically have a faculty advisor, creating opportunities for significant student-faculty interaction outside of the classroom. While classroom design projects provide numerous benefits for students, design competitions may motivate students to perform at a higher level than in class (Wankat, 2005). Lattuca, Terenzini, and Volkwein (2006a) found that participation in design competition was positively related to math, science, and engineering skills, design and problem-solving skills, group skills, and life-long learning. Competition may also provide students with a better sense of the "real world" and an understanding of the needs of the complete product cycle including scheduling, communication and coordination, budgeting, working within manufacturing limitations, and documenting work (R. J. Bennett, Ricci, & Weimerskirch, 2004).

Participation in a student chapter of an engineering professional society is another out-of-class activity thought to enhance engineering education. Lattuca, Terenzini, and Volkwein (2006a) found participation to be positively related to eight out of nine of ABET's EC2000 required learning outcomes. In particular, participation is thought to enhance students professional skills, such as teamwork, leadership, and awareness of societal issues (Emerson & Mills, 2003). Like participation in internships, cooperative education, and design competition, participation in a student chapter can be an important influence on student ability to apply engineering skills, work in groups, and appreciate the societal and global context of engineering.

Learning Outcomes

While there are many student outcomes of interest to higher education practitioners and theorists, the scope of this study and the available data required that the outcomes investigated be limited. Thirty-six items in the student survey allowed students to report on their outcomes. Factor analysis yielded nine scales which were categorized into areas of concentration: 1) math, science, and engineering skills; 2) project skills; and 3) contexts and professionalism (Lattuca et al., 2006a). This study will focus on one learning outcome from each of these broad groupings.

The first outcome of interest, ability to apply engineering skills (scale alpha = .94), was chosen from the math, science, and engineering skills cluster because it is the keystone of an engineering program. Without this foundational ability, engineering graduates could hardly be called engineers. The second outcome of interest, from the project skills group, is group skills (scale alpha = .86), chosen because it was key deficiency noted by employers prior to EC2000 (Prados et al., 2005). While the effects of EC2000 are not considered in this study, the increased focus on this group skills stimulated by EC2000 and industry interest make this outcome one of broad interest to both engineering faculty and employers. Finally, the third outcome of interest, from the contexts and professionalism group, is knowledge of societal and global issues (scale alpha = .92). Like group skills, academic and industry interest in this outcome is high, due to EC2000. In addition, increasing students' knowledge and understanding of societal and global issues is of broader interest to the postsecondary academic community (Bok, 2006; Nussbaum, 1997).

Data Cleaning

Cases with more than 20 percent of questions left unanswered were eliminated from the data set. In order to retain as many usable cases as possible, missing data in the remaining cases were imputed using the expected maximization method in SPSS Version 15. This method assumes that data are missing at random, such that the probability skipping a question is unrelated to a respondent's answer on that question (Allison, 2001). Such techniques are often applied with survey data because many statistical analyses require that every case has information on all the variables (for a complete discussion of expected maximization methods of data imputation, see Allison, 2001). All variables in the dataset were used in the imputation algorithm, but gender and race were not imputed (while gender and race were used to impute other missing items, both remain missing if students did not provide this information).

In order to determine the continuous improvement characteristics of a program when the continuous improvement variables were reported by individual faculty, these variables were aggregated at the program-level. Subsequently, in order to maximize the validity of program-level parameters, programs with very low faculty response (n<5 and response rate < 25%) or low student response (<20%) were eliminated from the sample. The resulting sample included 3,338 students (34% response rate), 1,037 faculty members (40% response rate), from 142 engineering programs in 39 institutions from a variety of institutional types (as defined by the Carnegie Foundation for the Advancement of Teaching, 2001).

Further, in order to maximize the generalizability of the data to the larger population, the survey data were weighted to correct for any deviations from the population distribution. In this technique, Chi-square Goodness-of-Fit tests was used to evaluate the representativeness of a sample as compared to the population and then a weight was applied to correct for under- or over-representation in the sample (Kalton, 1983). Faculty data were weighted by gender and discipline, and participation in a National Science Foundation (NSF) Engineering Education Coalition (adjusted n = 1,037). During the 1990s, the NSF funded ten, multi-institution coalitions focused on curricular and instructional innovation and reform in undergraduate engineering education (Volkwein et al., 2007). Faculty cases were weighted based on whether their program participated in NSF Coalitions because of the possibility that participation might influence the attention and resources given to curriculum planning. Student cases were weighted by gender and discipline (adjusted n = 3,333). The weighted student and faculty data are similar in distribution to both the sampling pool and the population (Tables 3.1 and 3.2).

Analytical Methods

This study tested the relationship between faculty culture, student experience, and student learning outcomes, as illustrated in the conceptual framework, using a three phase analytical approach. In order to test the ability of the continuous improvement variables to distinguish among programs and to validate the use of Briggs et al.'s (2003) continuous curriculum planning construct, cluster analysis was used in phase I to group the engineering programs in the sample by their level of continuous improvement related activities. In phase II, a hierarchical linear model was applied to assess the need for a two-level model which explored variance at the student-level and at the program-level. In phase III, path modeling techniques assessed the conceptual framework and the influence of continuous improvement level on the relationship between student characteristics, institutional characteristics, faculty culture, student experiences, and student outcomes hypothesized in the framework.

Phase I: Cluster Analysis

As the first phase in this analysis, cluster analysis tested the use of a variety of continuous improvement measures to classify engineering programs. The guiding question of interest was whether this set of variables could differentiate among engineering programs. This analysis extends the model established by Briggs et al. (2003) by adding several variables consistent with the tenets of continuous improvement and engineering accreditation standards. Thus, in addition to measures of continuous curriculum planning, the study explores the role of instructional development, participation in projects to improve undergraduate education, and participation in outcomes assessment to create a more comprehensive measure of continuous improvement commitment in academic programs.

The cluster analysis also tests the hypothesis that faculty attitudes are important predictors of program-level adoption of continuous improvement activities. Answering this question will contribute to the existing literature that posits a linkage between successful adoption of various improvement efforts with faculty buy-in. Although the literature provides some evidence to support the hypothesis, researchers have not attempted to show that faculty support for such initiatives can be used to predict their behaviors. Grouping the engineering programs in the *Engineering Change* database into different continuous improvement levels also allowed for a more extensive exploration of the relationship between continuous improvement and student learning in the later phases of this project.

Table 3.1: Characteristics of the Population of 2004 Graduates, Survey Respondents, and their Institutions

Characteristic	**244-Institution Population 2001 [a] (N = 46,035)**	**40-Institution Sample 2001 [a] (n = 12,144)**	**Respondents [b] (n =3,333) [c]**	**244-Institution Population 2004 [d] (N = 50,922)**
Individual				
Discipline				
Aerospace	2.8%	4.1%	2.8%	4.2%
Chemical	11.7	10.7	11.8	9.1
Civil	15.8	13.1	15.9	14.9
Computer	6.7	9.1	6.8	13.4
Electrical	31.2	33.2	30.8	26.2
Industrial	6.3	9.1	6.5	6.2
Mechanical	25.4	20.7	25.5	26.0
	100.0%	100.0%	100.0%	100.0%
Gender				
Male	80.3%	79.4%	79.1%	81.0%
Female	19.7	20.6	20.5	19.0
Did not respond			.4	
	100.0%	100.0%	100.0%	100.0%
Institution				
Institution Type [e]				
Research	82.8%	91.4%	90.4%	81.9%
Masters	13.3	6.7	6.3	13.7
Baccalaureate	3.8	1.9	3.3	4.4
	100.0%	100.0%	100.0%	100.0%
Control				
Public	76.6%	78.7%	76.7%	78.5%
Private	22.4	21.3	23.3	21.5
	100.0%	100.0%	100.0%	100.0%
Member of NSF Coalition				
Yes	35.8%	61.1%	52.3%	34.7%
No	64.2	38.9	47.7	65.3
	100.0%	100.0%	100.0%	100.0%
EC2000 Review Schedule				
Early	36.3%	43.0%	44.5%	37.5%
On-time	44.5	29.8	26.5	43.7
Deferred	19.2	27.2	29.0	18.8
	100.0%	100.0%	100.0%	100.0%

Note: Adapted from Lattuca et. al., 2006, p. 14.
[a] Source: American Society of Engineering Education.
[b] Weighted by discipline and gender.
[c] Weighted n may be smaller than unadjusted number of respondents due to missing data on a weighting variable.
[d] Source: American Society of Engineering Education – 2004 data was not available at the time of analysis.
[e] Based on 2000 Carnegie Classifications.

Table 3.2: Characteristics of the Faculty Population, Survey Respondents, and their Institutions

Characteristics	244-Institution Population 2001 [a] (N = 15,895)	40-Institution Sample 2001 [a] (N = 3,303)	Respondents [b] (n = 1,037)	244-Institution Population 2004 [c] (N = 14,884 [d])
Individual				
Discipline				
Aerospace	4.9%	8.0%	5.0%	3.8%
Chemical	9.6	8.7	10.6	10.9
Civil	17.0	15.4	17.7	18.8
Computer	9.4	12.6	9.1	8.1
Electrical	31.7	30.0	31.2	26.6
Industrial	5.9	6.5	5.9	6.7
Mechanical	21.5	18.8	20.6	25.1
	100.0%	100.0%	100.0%	100.0%
Gender				
Male	91.7%	91.7%	84.2%	90.6
Female	8.3	8.3	15.8	9.4
	100.0%	100.0%	100.0%	100.0%
Race				
White/European Amer.	65.4%	71.3%	72.3%	68.1%
Black/African Amer.	2.2	2.6	2.1	2.5
Hispanic/Latino/a	5.0	2.3	2.1	3.3
Asian	21.9	17.4	16.2	21.7
Am. Indian/Alask. Nat.	.1	.1	.3	.2
Hawaiian/Pacific Isl.	.1	.0	.2	.0
Other	.3	6.3	2.8	4.2
	100.0%	100.0%	101.5%[e]	100.0%
Institution				
Institution Type				
Research	87.4%	94.4%	88.3%	84.9%
Masters	9.5	4.1	7.4	11.6
Baccalaureate	3.1	1.5	4.2	3.5
	100.0%	100.0%	100.0%	100.0%
Control				
Public	76.2%	69.4%	68.5%	75.3%
Private	23.8	30.6	31.5	24.7
	100.0%	100.0%	100.0%	100.0%
Member of NSF Coalition				
Yes	34.7%	55.3%	34.6%	33.6%
No	65.3	44.7	65.4	66.4
	100.0%	100.0%	100.0%	100.0%
EC2000 Review Schedule				
Early	37.7%	37.8%	37.9%	37.3%
On-time	43.5	37.9	33.3	45.6
Deferred	18.8	24.3	28.8	17.1
	100.0%	100.0%	100.0%	100.0%

Note: Adapted from Lattuca et. al., 2006, p. 35.
[a] Source: American Society of Engineering Education.
[b] Weighted by discipline, gender, and NSF Coalition membership.
[c] Source: American Society of Engineering Education – 2004 data was not available at the time of analysis.
[d] Faculty population appears to decrease between 2001 and 2004 due to differences in the data source and counting rules. The faculty population actually increased over this time.
[e] Does not sum to 100% because some respondents selected more than one race/ethnicity.

Cluster Variables

As a first step in the analysis, four of the five continuous improvement variables (continuous curriculum planning, faculty instructional development, faculty participation in projects to improve undergraduate education, and faculty participation in assessment) were chosen to reflect a program's continuous improvement level. The fifth continuous improvement variable, a survey item measuring faculty enthusiasm for outcomes assessment, was reserved to validate the clusters established by the four continuous improvement variables. This variable was chosen as the validating variable due to the presumed influence of faculty support on continuous improvement behaviors.

Faculty cases were aggregated at the program level (e.g., Big State University, Electrical Engineering) on each of the continuous improvement variables and screened for normality. Data screening revealed that all but one of these variables, undergraduate education projects, were normally distributed or reasonably close to being so (Table 3.3). Although the distribution of the continuous curriculum planning and enthusiasm for outcomes assessment variables are somewhat leptokurtic (too peaked), the assumptions of a normal distribution are robust to such variations. The high kurtosis of the undergraduate education projects variable, however, suggests that outliers on this variable might be problematic.

Several standard transformations (e.g., square root, log 10, natural log) were performed on the undergraduate education projects variable to correct the kurtosis, but transformation failed to reduce it. In order to assess the impact of the kurtotic nature of the undergraduate education projects variable, this variable was then transformed into a dichotomous variable around the median.[12] The cluster analysis was performed twice, once on the set of variables including the original undergraduate education projects variable and once using the dichotomously-coded

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[12] Values less than the median were coded zero, and greater than the median were coded one. Values exactly on the median were alternately coded zero or one.

undergraduate education projects variable. The resulting clusters were compared and found to differ substantially, suggesting that the problem is a measurement issue, rather than a statistical one because the range of responses is too small to differentiate programs. Based on this result, the original undergraduate education projects variable was retained in the analysis despite its kurtosis in order to retain as much precision as possible.

Table 3.3: Cluster Analysis Data Screening

	Continuous Curriculum Planning	**Instructional Development**	**Undergrad. Education Projects**	**Enthusiasm - Outcomes Assessment**	**Participation - Outcomes Assessment**
N	142	142	142	142	142
Minimum	2.13	1.40	1.20	1.00	1.67
Maximum	4.63	2.67	2.81	4.00	4.00
Mean	3.4129	2.1086	2.1188	2.3870	2.6700
Std. Dev.	0.4295	0.2065	0.2035	0.4788	0.4764
Skewness*	0.1391	0.0523	0.0140	0.1787	0.2518
Std. Error	0.2034	0.2034	0.2034	0.2034	0.2034
Z-score	0.6839	0.2570	0.0689	0.8782	1.2376
Kurtosis*	0.8193	0.7808	4.1548	0.8525	-0.0823
Std. Error	0.4042	0.4042	0.4042	0.4042	0.4042
Z-score	2.0271	1.9319	10.2801	2.1093	-0.2037

* Normal values should be within the range (-2, 2), with 0 indicating a complete absence of skewness/kurtosis. The Z-score is a standardized version of these values and should be within the range of (-1.96, 1.96).

Cluster Technique

Engineering programs were then grouped using Ward's technique of hierarchical cluster analysis. Cluster analysis is a mathematical technique that attempts to identify relatively similar subgroups of cases within a sample or population based on multiple characteristics of interest (Milligan & Cooper, 1987). As in all agglomerative hierarchical cluster methods, Ward's approach begins by treating each case as a separate cluster, and then successively combining clusters into larger clusters. The clustering algorithm applied in Ward's method optimizes the minimum variance within clusters (Ward, 1963). This method was chosen from among the many hierarchical clustering algorithms because it has been shown to be one of the most effective methods for recovering clusters from simulated data sets with known cluster structures (Milligan & Cooper, 1987). In the analysis, squared Euclidean distance was the similarity measure used to form the clusters and all variables were standardized to z-scores. SPSS Version 13.0 was used to carry out all analyses.

Validating and Describing the Clusters

Because cluster analysis can yield groupings of cases that are not meaningful in the context of the research questions, cluster results should be tested for their stability and validity. In order to test the stability of the cluster solutions, a discriminant function analysis (DFA) using the cluster variables to predict cluster membership was performed. Like other multivariate techniques, the purpose of DFA is to examine several variables simultaneously (Tabachnick & Fidell, 2001). Validity of the clusters was tested using multivariate analysis of variance (MANOVA) with the cluster variables and faculty enthusiasm (the validator variable) as the predictor variables and cluster membership as the dependent variable. The data met the MANOVA assumption of equality of variance but Box's test indicated that the assumption of homogeneity of covariance matrices was violated. The F test, however, is robust to violations of this type.

Lastly, a series of Pearson's chi-square tests were applied to test potential associations between program characteristics and continuous improvement group. Institutional control (public or private), participation in an NSF Engineering Education Coalition, engineering discipline, and year of EC2000 adoption were each tested to determine whether inclusion in a particular continuous improvement group was statistically related to any of these characteristics.

Phase II: Hierarchical Linear Model

As a second step in the analysis, hierarchical linear modeling (HLM) was used to determine the degree to which student learning outcomes are due to programs and the degree to which they are due to student pre-college characteristics. In this step, continuous improvement level, as determined from the cluster analysis, tested as a predictor of learning outcomes. In most studies of learning outcomes, individual student characteristics and the characteristics of their academic program or institution are confounded because students are not randomly assigned to institutions or majors. With students as the desired unit of analysis, traditional linear regression techniques require that all higher order variables be disaggregated to the individual student level. This approach results in students in the same program having the same value on all program- and institution-level variables, violating the independence of observations assumption of most linear models. The use of hierarchical linear models (HLM), also known as multilevel models, is advantageous over traditional regression techniques for this analysis because it recognizes the dependence of student-level variables and treats groups in the sample as a random sample from a population of groups, allowing for inference to the population. Detailed presentations of HLM are available elsewhere (e.g., Raudenbush & Bryk, 2002). Of particular importance to the present analysis, is the focus of HLM on the grouping variable, in this case continuous improvement level, and its effect on the learning outcomes of interest.

The analyses for the multilevel model were conducted using the Hierarchical Linear and Non-Linear Modeling (version 6.04) statistical package (Raudenbush, Bryk, & Congdon, 2007). The two-level model included 3,333 students at level-one and 142 engineering programs at level-two (programs). Although institutional characteristics introduce a potential third level, in which programs are nested, their effects on students have been demonstrated to be too distant from student experiences to have strong direct effects on student outcomes (Pascarella & Terenzini, 2005). For this reason and because institution-level effects were not of interest in this analysis, these variables were entered at the program-level. Two-level models were tested for each of the three learning outcomes of interest.

Because HLM is based on linear regression, it remains the case that the intercept is the valued of Y when X is equal to zero. For many variables (e.g., SAT scores) values of zero do not naturally occur. By centering variables like these on the grand mean, their interpretation is clearer. Following standard HLM convention (Raudenbush & Bryk, 2002), the level-one variables, parents' income, SAT, and high school GPA were centered around the ground mean. The level-two variables, institutional size and institutional wealth, were already standardized to z-scores in the initial dataset, so centering was unnecessary. Dummy-coded variables level-one variables for gender and minority status and the level-two variables for continuous improvement level were not centered.

A one-way ANOVA with random effects provided the preliminary model (Equation 3.1).

$$\mathrm{Y}_{ij} = \gamma_{00} + u_{0j} + r_{ij} \qquad \text{Equation 3.1}$$

This model addresses the initial question of whether engineering programs vary significantly in their mean student learning outcomes. The second model introduced the level-one control variables: gender, parents' income, total SAT score, high school GPA, and race, with White as the referent (Equation 3.2).

$$\begin{aligned}
\mathrm{Y}_{ij} &= \gamma_{00} + \gamma_{10} * Gender_{ij} + \gamma_{20} * (Income_{ij} - Income_{..}) + \\
&\gamma_{30} * (SAT_{ij} - SAT_{..}) + \gamma_{40} * (GPA_{ij} - GPA_{..}) + \gamma_{50} * Minority_{ij} + \\
&u_{0j} + u_{1j} * Gender_{ij} + u_{2j} * (Income_{ij} - Income_{..}) + u_{3j} * \\
&(SAT_{ij} - SAT_{..}) + u_{4j} * (GPA_{ij} - GPA_{..}) + u_{5j} * Minority_{ij} + r_{ij}
\end{aligned} \qquad \text{Equation 3.2}$$

Model three introduced the level-two control variables institutional size and wealth (Equation 3.3).

$$
\begin{aligned}
&\mathrm{Y}_{ij} = \gamma_{00} + \gamma_{01} * Size_j + \gamma_{02} * Wealth_j + \gamma_{10} * Gender_{ij} + \gamma_{11} * \\
&Size_j * Gender_{ij} + \gamma_{12} * Wealth_j * Gender_{ij} + \gamma_{20} * \\
&(Income_{ij} - \overline{Income}_{..}) + \gamma_{21} * Size_j * (Income_{ij} - \overline{Income}_{..}) + \gamma_{22} * \\
&Wealth_j * (Income_{ij} - \overline{Income}_{..}) + \gamma_{30} * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{31} * \\
&Size_j * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{32} * Wealth_j * (SAT_{ij} - \overline{SAT}_{..}) + \\
&\gamma_{40} * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{41} * Size_j * (GPA_{ij} - \overline{GPA}_{..}) + \\
&\gamma_{42} Wealth_j * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{50} * Minority_{ij} + \gamma_{51} * Size_j \\
&* Minority_{ij} + \gamma_{52} Wealth_j * Minority_{ij} + u_{0j} + u_{1j} * Gender_{ij} \\
&+ u_{2j} * (Income_{ij} - \overline{Income}_{..}) + u_{3j} * (SAT_{ij} - \overline{SAT}_{..}) + u_{4j} * \\
&(GPA_{ij} - \overline{GPA}_{..}) + u_{5j} * Minority_{ij} + r_{ij}
\end{aligned}
\qquad \text{Equation 3.3}
$$

The final model is the continuous improvement model, which introduced continuous improvement level, at level-two (Equation 3.4). Given significant level-two (program) differences, this model was used to test whether there is a relationship between programs' continuous improvement level and individual student learning outcomes net of the influence of important student and institutional characteristics. Student experiences are not included in the model as mediators between pre-college and institutional characteristics because HLM is unable to model mediator variables and would, consequently, provide misleading results.

$$
\begin{aligned}
&Y_{ij} = \gamma_{00} + \gamma_{01} * CI_j + \gamma_{02} * Size_j + \gamma_{03} * Wealth_j + \gamma_{10} * Gender_{ij} + \\
&\gamma_{11} * CIj * Gender_{ij} + \gamma_{12} * Size_j * Gender_{ij} + \gamma_{13} * Wealth_j * \\
&Gender_{ij} + \gamma_{20} * (Income_{ij} - \overline{Income}_{..}) + \gamma_{21} * CI_j * (Income_{ij} - \\
&\overline{Income}_{..}) + \gamma_{22} * Size_j * (Income_{ij} - \overline{Income}_{..}) + \gamma_{23} * Wealth_j * \\
&(Income_{ij} - \overline{Income}_{..}) + \gamma_{30} * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{31} * CI_j * \\
&(SAT_{ij} - \overline{SAT}_{..}) + \gamma_{32} * Size_j * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{33} * Wealth_j * \\
&(SAT_{ij} - \overline{SAT}_{..}) + \gamma_{40} * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{41} * CI_j * (GPA_{ij} - \\
&\overline{GPA}_{..}) + \gamma_{42} * Size_j * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{43} * Wealth_j * (GPA_{ij} - \\
&\overline{GPA}_{..}) + \gamma_{50} * Minority_{ij} + \gamma_{51} * CI_j * Minority_{ij} + \gamma_{52} * Size_j * \\
&Minority_{ij} + \gamma_{53} * Wealth_j * Minority_{ij} + u_{oj} + u_{1j} * Gender_{ij} + \\
&u_{2j} * (Income_{ij} - \overline{Income}_{..}) + u_{3j} * (SAT_{ij} - \overline{SAT}_{..}) + u_{4j} * (GPA_{ij} \\
&- \overline{GPA}_{..}) + u_{5j} * Minority_{ij} + r_{ij}
\end{aligned}
\qquad \text{Equation 3.4}
$$

Phase III: Path Analysis

In the final step of the analysis, the structural equation modeling (SEM) technique of path analysis was used to test the hypothesized causal relationships in the conceptual framework. SEM is a confirmatory technique for testing theoretical causal relationships between variables and was chosen for the analysis because 1) it is one of the only approaches that allows for concurrent tests of all relationships in a complex model including multiple dependent variables, 2) it allows for the incorporation of mediating variables, 3) and it is more rigorous for parsimonious model testing than multiple regression analysis (Tabachnick & Fidell, 2001). SEM techniques test whether the hypothesized model generates an estimated population covariance matrix that is consistent with the covariance matrix observed in the sample (Lei & Wu, 2007). A model generating approach was taken in all analyses, allowing for theoretically reasonable revisions of the model based on the results of the initial model test (Jöreskog, 1993).

LISREL Version 8.80 was used in all path analyses. With a dataset comprised of mixed scale types (ordinal, continuous, and dichotomous), the use of a polychoric correlation matrix with weighted least squares estimation is the preferred approach, however this requires an extremely large sample size (Byrne, 1998; Jöreskog, 1990). Although large, the sample size in this dataset was insufficient to support this approach, so the analyses were based on covariance and asymptotic covariance matrices applied with robust maximum likelihood estimation (MLE). Robust MLE yields the best possible estimations when variables do not exhibit a normal distribution, as is the case with several of the variables in the dataset (see Appendix B). This method allows for the use of the Sattora-Bentler test statistic, which is corrected for the degree of observed kurtosis in the data (Kline, 2005). The covariance matrix was used in the data analysis and the asymptotic covariance matrix was applied to calculate the Sattor-Bentler test statistics.

In order to use robust MLE, all endogenous variables should be continuous. In order to meet this requirement, the three ordinal student out-of-class experience variables (time spent in internships and co-operative education, time spent in non-required design competitions, and level of participation in student chapters of professional societies) were standardized and summed to create the student Co-curricular Experience variable. LISREL default start values, convergence criterion, and iteration cycles were used for all models.

The first step in the path analysis was model specification based on the *a priori* model established by the conceptual framework (Figure 3.2). Because the final step in the path analysis was a comparison of the model fit between the high- and low-CI programs, continuous improvement level is not a predictor in the model and institution characteristics are represented as direct effects on student experiences, although they are not expected to be strong. In the second step, model identification was verified. Identification means that the model does not have a larger number of unknown parameters than there are unique pieces of information provided by the data.

Because the initial model is recursive (has no feedback loops, reciprocal causation, or correlated disturbances) it is structurally identified (Kline, 2005).

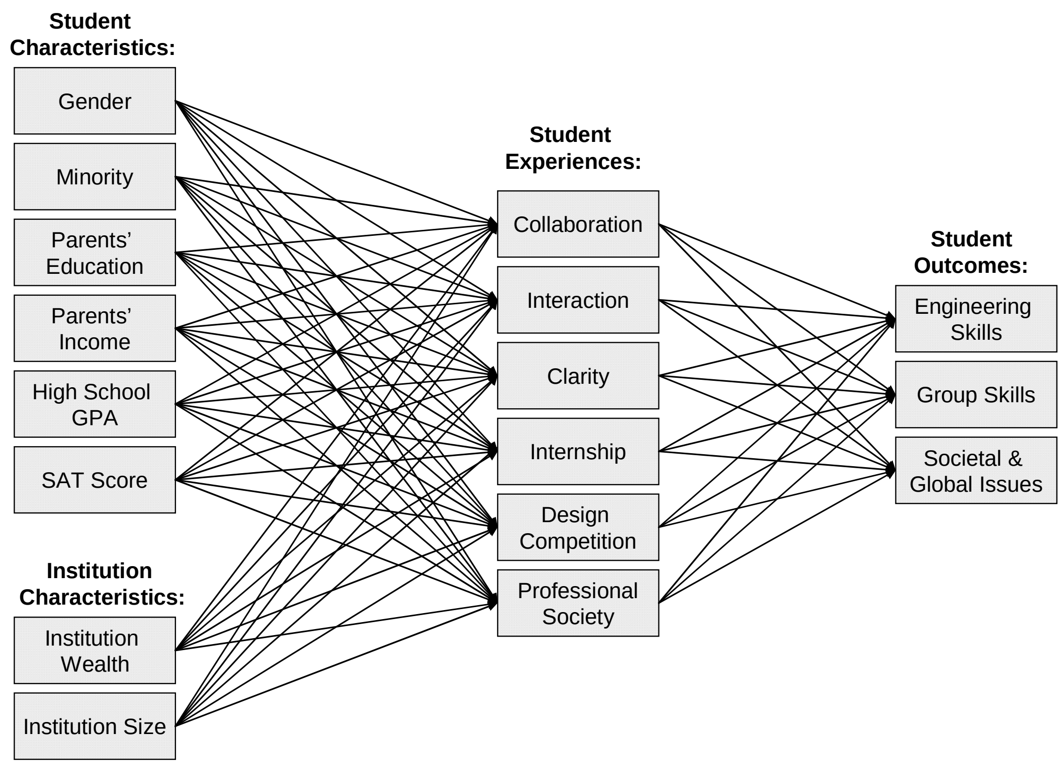

Figure 3.2: Initial Model Specification

Once the model was specified and identified, it was evaluated for goodness-of-fit using multiple goodness-of-fit test statistics. Chi-square tests form the starting point for such testing, but often lead to the rejection of reasonable models tested with large samples (Lei & Wu, 2007). Given the large sample size, additional fit indices, including the root mean-squared error, incremental and absolute, were applied to test the model (Hu & Bentler, 1999). Following the recommendations of Lei and Wu (2007) the model chi-square is reported alongside additional fit indices in the results.

Although researchers often focus on goodness-of-fit of the overall model, individual parameter estimates should also be examined for statistical significance to verify that all aspects of the structural model are reasonable. Parameter estimates were examined for statistical significance as well as consistency with the underlying theory (for example, does a relationship anticipated to be positive, yield a negative estimate in the model?). A final consideration in evaluating the model fit was the size and distribution of the residuals, which indicate the magnitude of the difference between the actual values and those predicted by the model.

Using a model-generating approach, an initial model that is rejected, based on its overall goodness-of-fit, may be re-specified and re-tested. Modification indices provided by the software package can be used to identify changes that are likely to improve the model fit, however, relying on these indices may lead to false, although statistically sound, models. Because of this danger, Lei and Wu (2007) warn against making large numbers of changes or changes that are not grounded in theory when re-specifying a model. Although this analysis takes a model-building approach, modifications to the model after initial specification were undertaken cautiously with both theory and statistical significance considered before any changes were made.

Once a theoretically sound model with reasonable fit was established, a multiple group path analysis was undertaken to assess whether the established model differed significantly for the high- and low-CI programs. First an equality constraint for the high- and low-CI programs was imposed on each path. The fit (Satorra-Bentler chi-square) for the joint model in which all paths are set to be equal for high- and low-CI programs (the constrained model) was compared to the fit for the joint model in which all parameters were free to vary (the unconstrained model). If the unconstrained model fits better than the constrained model, as established by the chi-square difference test for the Satorra-Bentler scaled chi-square, the model differs significantly between high- and low-CI programs. This approach examines the moderator effect of the continuous improvement level of students' engineering programs by comparing the relations between variables in the model in the continuous improvement groups, allowing the researcher to explore whether program continuous improvement level influences the relationships between student characteristics, student experiences and student learning outcomes (Kline, 2005).

Chapter 4

FINDINGS

A three-phase analysis explored the influence of continuous improvement on student learning. The first phase sought to validate the use of four variables identified as reflecting a program's commitment to continuous improvement and to divide the sample programs based on these measures. Using the continuous improvement groups identified in phase I, the second phase of the analysis sought to determine whether a program's continuous improvement level exhibited a direct influence on three student learning outcomes – engineering skills, group skills, and knowledge of societal and global issues. Guided by the study's conceptual framework, the final phase explored the relationships between student and institutional characteristics, students' in- and out-of-class experiences, and the three learning outcomes. With a model developed from the framework and validated in the data, separate models were fit for the continuous improvement groups indentified in the first phase of the study. Using this approach, the study examined the indirect influence of continuous improvement on the entire model.

Cluster Analysis

Choosing the Optimum Number of Clusters

Two-, three-, and four-cluster solutions were initially produced as part of the exploratory cluster analysis. Following the recommendations of Rapkin and Luke (1993), a number of factors were considered to determine which solution created the optimal number of clusters, including: 1) the number of cases within clusters, 2) one-way ANOVA effects on profile variables (the variable used to create the clusters), 3) multivariate effects on profile variables, 4) stability of cluster solutions, and 5) interpretability of the clusters. Evaluation of the partial eta-squared values for each measure indicate that substantial increases in variance are explained due to the break out of each new cluster group (Table 4.1). The two-, three-, and four-cluster solutions explain 59%, 79%, and 89% of the joint distribution of the measures respectively.

Table 4.1: Variance Explained by Cluster Solutions (n of cases = 142)

	Number of Clusters		
	2	3	4
Profile Variables			
Continuous curriculum planning	12.2%	37.5%	37.9%
Instructional development	35.4	45.0	57.3
Undergraduate education projects	17.2	20.3	32.1
Participation in outcomes assessment	40.6	47.4	60.0
1 – Wilks' Lambda	.586	.787	.885
Roy's Largest Root	1.414	3.190	3.204
Smallest group n	67	11	11

Clustering cases maximizes group differences on the variables of theoretical interest (Rapkin & Luke, 1993). Therefore, one-way analyses of variance should reveal statistically significant differences in the mean values of the profile variables between clusters. If this is not the case, it suggests that additional clusters may be needed to differentiate groups on the profile variables. In post hoc[13] comparisons of the profile variables on the three- and four-cluster solutions, the majority of pairwise comparisons (see Appendix C) exhibited significant mean differences between the clusters ($p < .05$). Further, a discriminant function analysis using the profile variables to predict cluster membership resulted in correct predictions for 91% of the cases in the two-cluster solution, 92% in the three-cluster, and 94% in the four-cluster. Although these number of correctly classified cases is likely to be inflated because the same cases were used to classify and to discriminate, these results indicate that all of the cluster solutions are stable.

[13] Tukey's honest significant difference (HSD) was used for the four-cluster solution, and the Fisher least significant difference (LSD) post hoc test for the three-cluster solution.

Once the cluster stability has been established, the next step is to test their validity. One method of establishing validity is to test whether the profile variables together with the reserved validating variable are able to predict cluster membership using a multivariate analysis of variance. In this case, a variable measuring "faculty enthusiasm for outcomes assessment" was used as a proxy for faculty support for continuous improvement. If, as posited by Welsh and Metcalf (2003) and others, faculty buy-in is a requirement for successful adoption of institutional improvement activities, then faculty enthusiasm for outcomes assessment should be a reasonable predictor of program level of continuous improvement activities.

Multivariate analysis of variance using the original four profile variables plus faculty enthusiasm as the predictor variables revealed all of the profile variables and the faculty enthusiasm variable to be significant predictors of cluster membership in each of the cluster solutions ($p < .001$). These results theoretically validated the two-, three-, and four-cluster solutions and provided support for the argument that faculty attitudes are a critical predictor of successful implementation of continuous improvement and other institutional improvement practices.

Although the stability and validity of the three- and four-cluster solutions were established, the two-cluster solution was determined to be the best solution for use in future analyses. In both the two- and three-cluster solutions, the relationship between the program groups on each of the continuous improvement variables is consistent (e.g., programs that were highest on one variable, were highest on all variables), making these solutions clearly interpretable. The four-cluster solution, in contrast, yielded groups without this consistency. Further, in both the three- and four-cluster solution, one group held only 11 programs, while the other groups were at least three times as large. Because the cluster groupings are the basis for additional analysis using large-sample statistical techniques (hierarchical linear modeling and path analysis) in phases II and III of this study, the two-cluster solution was selected to differentiate the programs based on the interpretability of the clusters and the number of programs within the clusters. The two-cluster solution yielded a clear and consistent high/low relationship between the clusters, where the mean value of group one was significantly higher than that for group two for each of the continuous improvement variables (Figure 4.1). Subsequently, clusters one and two were renamed the high-CI (continuous improvement) group and the low-CI group respectively.

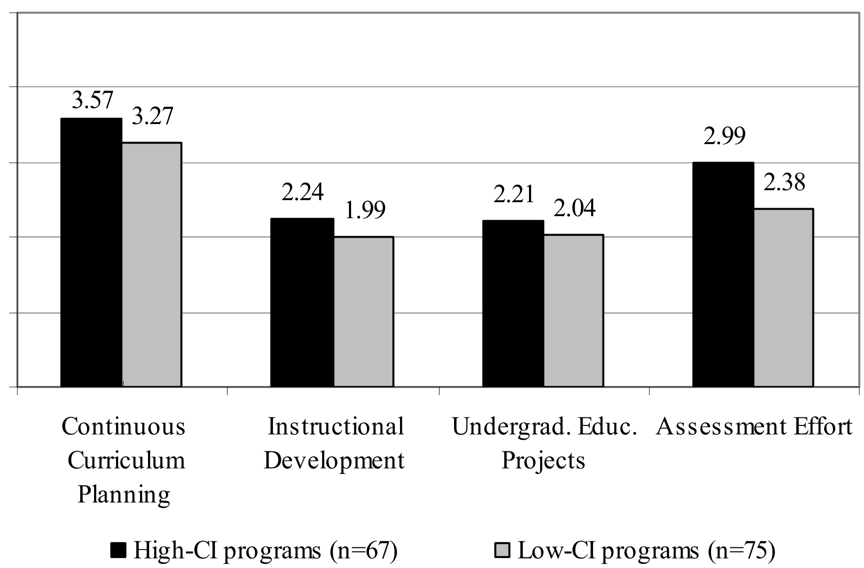

Figure 4.1: Mean Values for the Two-Cluster Solution

Note: Continuous curriculum planning was measured on a five-point scale, Instructional Development and Undergraduate Education Projects on a 3-point scale, and Assessment Effort on a four-point scale.

Differences between the High and Low Continuous Improvement Programs

The EC2000 standards where phased into use during the years 1998-2000. Engineering programs that came up for reaccreditation during this transition period had the option to "defer" the adoption of the EC2000 standards until they became mandatory or to meet them "early."

Programs seeking accreditation or reaccreditation after 2000 were required to meet the new standards and were considered “on-time” adopters. This phased implementation led Volkwein and colleagues (2006) to hypothesize that adoption status (early, on-time, or deferred) might reflect programs’ ability to meet EC2000’s requirements, among these being the incorporation of continuous improvement practices. The present comparison of the high and low clusters using a Pearson chi-square analysis, however, indicated no relationship between cluster membership and adoption status. This finding supports those of Volkwein et al., who concluded that by the time the *Engineering Change* study commenced in 2004 and the EC2000 standards were mandatory for all programs, there were few differences between programs because all were moving toward compliance with the new accreditation standards.

Pearson chi-square analyses of the two-cluster solution on a number of other institutional variables revealed few statistically significant differences between the high and low continuous improvement programs. Programs in either group are not more likely to be in public or private institutions, to have participated in a NSF Engineering Education Coalition (or not), or to be representative of any one engineering discipline over the others. Carnegie classification, however, was a significant determinant of group membership, with bachelor’s and master’s institutions overrepresented in the high continuous improvement group and research universities (research intensive and extensive) overrepresented in the low group ($p = .021$).

Hierarchical Linear Models

The one-way ANOVA with random effects, Model 1, indicated significant program-level variation in the three student outcomes of interest – engineering skills, group skills, and knowledge of societal and global issues ($df = 141$, $p < .001$). Only two percent of the variance in engineering skills and knowledge of societal and global issues, and three percent of the variance in group skills, however, is between programs. Although these low intraclass correlation coefficients (ICC) suggest that a two-level model may not be the best approach despite the significant program-level variation, some analysts argue that over-reliance on the size of the ICC can lead to the premature abandonment of a multilevel model. In some cases, the addition of predictor variables into the model can result in a higher group dependence than might be expected from a low ICC in the initial model (Roberts, 2007). For this reason, and because of the multilevel nature of the students in programs, model building continued.

The addition of the level-one covariates -- gender, income, SAT score, high school GPA, and minority status – in Model 2 accounted for small proportional reductions of within program variance (five percent in engineering skills, three percent in group skills, and two percent in knowledge of societal and global issues). The introduction of these variables at level-one however, substantially changed the variance between program outcomes. Level-two proportion reduction of unexplained variance in engineering skills *increased* by 30 percent, while *decreasing* by 42 percent in group skills and by 43 percent in knowledge of societal and global issues. These results suggest that these individual student characteristics make relatively small contributions to differences in outcomes within programs but that they heavily impact the differences between engineering programs.

As would be expected, the addition of the level-two covariates – institution size and institution wealth – in Model 3 did not change the level-one variance components meaningfully. At the program level, the addition of level-two covariates *increased* the between-program variance in engineering skills by five percent and in knowledge of societal and global issues by two percent. The level-two covariates *decreased* the between-program variance in group skills by nine percent. These results suggest that institution size and wealth actually decrease the explanatory power of the models for engineering skills and knowledge of societal and global issues. Although their addition decreased the amount of variance in the group skills model, neither size nor wealth significantly influenced the outcome or had a significant interaction with the other predictors.

Model 4 incorporated the dichotomous variable, continuous improvement, which identifies programs as low-CI or high-CI, as a level-two predictor. The inclusion of this independent variable did not improve the overall model measurably. Level-one variance remained relatively stable, as expected. Level-two variance *increased* six percent for engineering skills and *decreased* negligibly for group skills and knowledge of societal and global issues (two and three percent, respectively). Continuous improvement level was not significant ($p \leq .05$) in any of the models (Table 4.2; see Appendix D for the model's fixed effects). Levene's independent t-test comparing the outcomes of the high- and low-CI groups found no significant difference between the groups on the three outcomes, further confirming the finding that continuous improvement level does not directly influence student learning (Table 4.3).

The results of the HLM models suggest two things. First, they indicate that program-level variance is relatively small, indicating that a single-level model with students as the unit of analysis is appropriate. Second, Model 4 suggests that the influence of a program's continuous improvement level may not be, in and of itself, a significant predictor of student outcomes. This finding indicates the effect of continuous improvement level, if any, may be in moderating the relationships between student precollege characteristics, college experiences, and learning outcomes. A multiple group path analysis was used to explore this hypothesis.

Table 4.2: Chi-Square and P-Values for Random Effects on the HLM Models

Random effects	**Model 1 (df=141)**	**Model 2 (df=91)**	**Model 3 (df=89)**	**Model 4 (df=88)**
		Engineering Skills		
Program mean u_{0j}	20.35***	75.40	72.93	72.95
Gender-engineering skills slope, u_{1j}		69.36	63.34	63.63
Income-engineering skills slope, u_{2j}		79.43	78.38	78.32
SAT-engineering skills slope, u_{3j}		85.76	85.29	83.82
GPA-engineering skills slope, u_{4j}		117.71*	117.86*	115.30*
Minority-engineering skills slope, u_{5j}		97.55	96.24	96.08
		Group Skills		
Program mean u_{0j}	228.56***	66.35	62.87	62.78
Gender-engineering skills slope, u_{1j}		46.70	45.72	45.75
Income-engineering skills slope, u_{2j}		81.44	81.17	80.39
SAT-engineering skills slope, u_{3j}		103.43	102.57	102.67
GPA-engineering skills slope, u_{4j}		76.43	76.43	76.07
Minority-engineering skills slope, u_{5j}		115.79*	112.02*	108.97
		Knowledge of Societal and Global Issues		
Program mean u_{0j}	216.52***	78.96	75.11	75.13
Gender-engineering skills slope, u_{1j}		70.04	69.33	69.77
Income-engineering skills slope, u_{2j}		84.14	84.26	84.35
SAT-engineering skills slope, u_{3j}		87.20	86.75	86.93
GPA-engineering skills slope, u_{4j}		110.48	110.66	110.43*
Minority-engineering skills slope, u_{5j}		102.8	100.16	100.04

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Note: The chi-square statistics reported for Models 2, 3, and 4 are based on only 92 of 142 cases that had sufficient data for computation (e.g., programs with a sufficient number of students).

Table 4.3: Results of T-Test Comparing High- and Low-CI Group Outcomes

Outcome	**Mean difference**	**p-value**
Engineering skills	.048	.075
Group skills	.006	.815
Global and Societal Issues	.008	.778

Path Analysis

Initial Path Model for All Students

Overall Model Fit

The initial fit of the data to the model based on the linear sequence presented in the conceptual framework was poor. The Sattora-Bentler chi-square value was significant at the .01 level (degrees of freedom = 33), indicating that the data did not fit the hypothesized model well (Table 4.4). While the chi-square statistic is an overly sensitive evaluation of model fit in the presence of large sample size (Lei & Wu, 2007), poor fit was confirmed by a selection of fit indices including the root mean-square error of approximation (RMSEA). The RMSEA is the preferred fit index because this value takes into consideration the error of approximation in the model and its complexity. The 90% confidence interval for the RMSEA (.12 ; .13) was narrow, indicating the precision of the value and confirming the conclusion of poor fit. Overall, the weight of the evidence indicates that the initial model was misspecified.

Table 4.4: Selected Fit Indices for Initial Path Model

	Initial model fit:	**Indicative of good fit:**
Normal theory weighted least squares χ^2	3819.41 (p = 0.0)	p > .01
Satorra-Bentler χ^2	1500.82 (p = 0.0)	p > .01
Root mean-square error of approximation	.12	< .05
Normed fit index	.85	> .90
Comparative fit index	.85	> .90
Goodness-of-fit index	.85	> .90
Standardized root mean-square residual	.11	< .10

Component Fit

The component fit of the hypothesized model suggests that the model has value (Figure 4.2; see Appendix E for the dataset covariance matrix and full structural equations related to all path models). Significant relationships between variables were consistent with the hypothesized relationships. For example, women were significantly more likely than men to report that the often worked collaboratively and all four student experiences with significant effects on student learning indicated a positive influence. Following the conceptual framework, the initial model included paths from all student and institution characteristics to all student experiences and from all student experiences to all student learning outcomes, however, as anticipated, the relationship between parents' education level and instructor clarity and between family income and instructor clarity was not significant. The remainders of the paths were included because they were hypothesized to represent significant relationships. The initial model test did not, however, find all of them to be significant at the .05-level. Minority status and high school GPA, for example, were not significant predictors of any of the student experiences. While nonsigificant parameters often indicate insufficient sample size, that is unlikely to be the case in this sample, suggesting that these paths should be trimmed from the model. Additional evidence of poor fit is the presence of 32 standardized residuals greater than two and the failure of the residuals to follow a 45-degree angle on a Q-plot, both indicative of a misspecified model (Byrne, 1998).

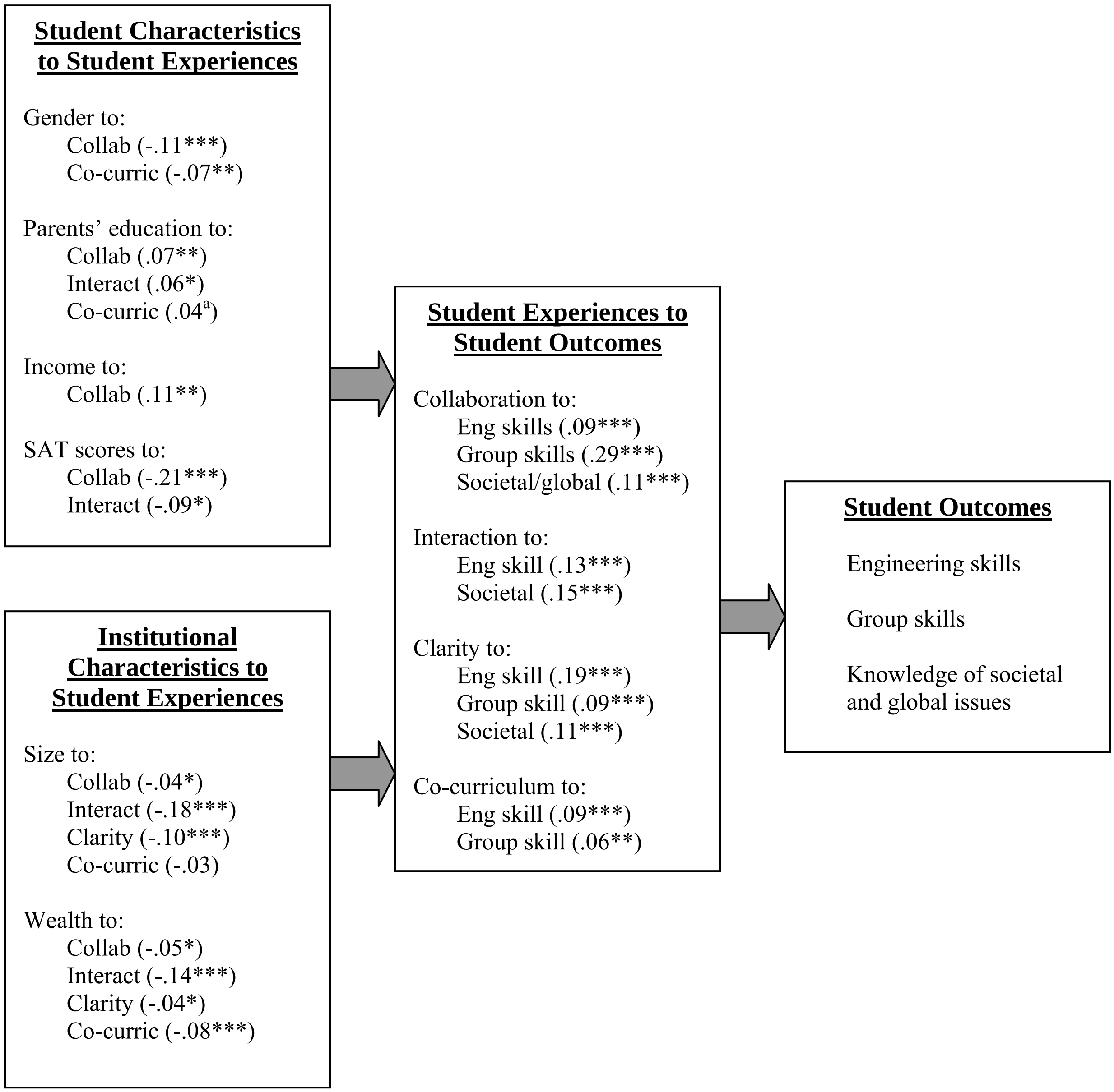

Figure 4.2: Significant Standardized Initial Model Components

* p = .05, ** p =.01, *** p = .001
[a] p = .06

Despite the evidence of misspecification, several factors indicate that this model has value. The standard errors of the component paths were not unreasonably large, ranging from .005 to .139, with the majority being .010 or less. The reduced R^2 values are small (Table 4.5); this was not unexpected, however, given the narrow focus of the model on student experiences that might be influenced by continuous improvement efforts, to the exclusion of focal topics in the curriculum, which would be expected to explain the bulk of the variance in learning outcomes. Although the explanatory power of the individual prediction equations is small, a theory-guided post-hoc re-specification of the model is appropriate.

Table 4.5: Reduced R^2 Values for the Endogenous Variables in the Initial Model

Outcome	**Reduced R^2**
Collaboration	.07
Interaction	.07
Clarity	.02
Co-Curriculum	.03
Engineering Skills	.01
Group Skills	.01
Societal & Global Issues	.01

Intermediate Model for All Students

Justification

The first step in model re-specification was to delete the nonsignificant paths, creating a new model nested within the initial model (Figure 4.3). While nonsignificant parameters can indicate insufficient sample size, that is not be the case here, suggesting that these paths should be removed from the model. Subsequently, all nonsignificant paths except that between high school GPA and co-curriculum were removed. Although not statistically significant, this path was retained because its removal substantially decreased the model fit and it is reasonable to expect that good students (as reflected by high school GPA) will spend more time in co-curricular activities directly related to the major. Many of the paths between student characteristics and student experiences were removed in this step. Initially included in the model to control for student pre-college experiences and to determine the effect of student college experiences net of these characteristics, the failure of these variables to predict student experiences is not surprising given the nature of the student sample. As seniors in engineering, the students in the sample have already been accepted into and are successful in a competitive and academically difficult major. Engineering students are relatively homogenous in their pre-college characteristics. Students for whom pre-college academic ability, family income, parents' education, gender, race/ethnicity negatively influenced their experiences are less likely to persist to the senior year than their peers.

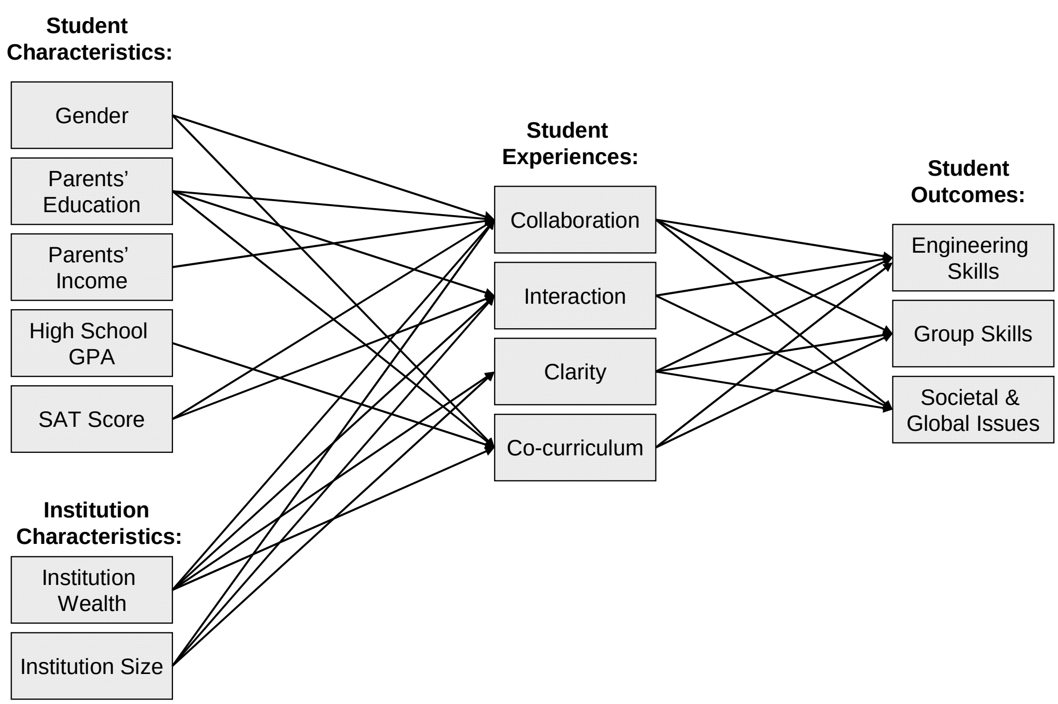

Figure 4.3: Intermediate Model

The lack of relationship between institution size and student participation in co-curricular activities is somewhat surprising. We typically anticipate that as the size of an institution increases, the proportion of students that actively participate in the co-curriculum decreases and the activities in which students participate become more specialized, rather than broad, as would be indicated by a high co-curricular composite score (Chickering, 1969). Thus, common perception is that students in larger institutions are less involved in out-of-class activities than their counterparts at small schools. This result, however, suggests that as the size of the school increases, so do the opportunities for student involvement, leading to no significant relationship between institution size and student participation in co-curricular activities related to the major.

Another aspect of the model not born out by the data is that instructor interaction would positively influence students' group skills. This proposed relationship was based on the initial conceptual framework and founded on the expectation that instructor interaction would stimulate student interaction and positively affect the nature of interactions among groups formed as part of class assignments. It may be however, that instructor interaction that is not specifically focused on supporting group interactions is not sufficient to influence students' group skills.

Of the nonsignificant relationships in the initial model, the relationship between students' participation in co-curricular activities and their knowledge of societal and global issues is most difficult to explain. The components of this item – internship and co-operative education, participation in design projects, and participation in professional societies – focus primarily on job-related skills and activities. Given that the practice of engineering occurs in an increasingly global environment, level of participation in such activities was anticipated to be positively related to students' knowledge of global and societal issues, but this was not the case. This finding was consistent with the findings of Lattuca et al. (2006) that employers were least likely to view this skill as important in new hires (in comparison to other skills), suggesting that entry-level positions do not stress global contexts, but rather focus more narrowly on technical and design skills. Another explanation may be that despite ABET's stress on this learning outcome, the importance of global and societal issues has not filtered down to most programs.

Intermediate Model Fit

With the removal of the nonsignificant paths, the model remained recursive and identified. The removal of nonsignificant paths from a "comparison" model without additional changes yields a new model that is "nested" within the original model. When the model fit indices of the comparison and nested models have similar explanatory power and do not differ significantly, as tested using the chi-square difference test, the more parsimonious nested model with fewer estimated parameters is retained. The nested model yielded a slight improvement over the comparison model based on the RMSEA, normed fit index, and comparative fit index, but it was still unable to account for the data adequately and the residuals showed no meaningful improvement. The goodness-of-fit statistics for both models were similar (Table 4.6) and the chi-square difference test for the Satorra-Bentler scaled statistic (2.8172, df=13) failed to reject the hypothesis that the two models differed significantly at the .05-level, indicating that the more parsimonious intermediate model should be retained.

Table 4.6: Selected Fit Indices for Intermediate Path Model.

	Intermediate Model (df = 46)	**Initial Model (df = 33)**
Normal theory weighted least squares χ^2	3893.89 (p = 0.0)	3819.41 (p = 0.0)
Satorra-Bentler χ^2	1243.94 (p = 0.0)	1500.82 (p = 0.0)
Root mean-square error of approximation	.10	.12
Normed fit index	.87	.85
Comparative fit index	.87	.85
Goodness-of-fit index	.84	.85
Standardized root mean-square residual	.12	.11

Final Re-specified Model for All Students

Justification and Changes to the Model

Post-hoc modifications to path models most often take one of two forms: the addition or deletion of paths and the addition of error covariances between variables. The addition or deletion of a path reflects a hypothesized direct relationship between two variables. While often presented as causal relationships, such conclusions cannot be made from cross-sectional data. The addition of an error covariance between two variables suggests that other variables may exist which explain more of the variance between the variables than the direct relationship. This strategy acknowledges that the model is incomplete. Adjustments to the model should consider the modification indices in light of what the researcher knows or hypothesizes about the relationships between variables. While it is possible to use modification indices to repeatedly fine-tune the model, thereby achieving better and better statistical fit, the goal is to specify theoretically sound additional parameters until “minimally adequate fit” is achieved (Byrne, 1998). To continue beyond this point is to overfit, creating a model that reflects only the dataset with which it was created and is unlikely to be validated through replication. Post-hoc model specification is an exploratory model-building procedure rather than a confirmatory model-testing procedure and should be interpreted with this in mind.

The modification indices from the initial and intermediate models suggested that the data do not necessarily reflect a linear series of events in which student and institutional characteristics influence student experiences which then influence student outcomes. Not surprisingly, the indices suggest that experiences influence each other and that the variables designated as student outcomes influence student experiences. Because the data were not collected over time with a single cohort of students, it is not possible to determine for certain whether a particular experience preceded an outcome, an outcome stimulated student participation in a particular activity, or whether one experience or one outcome influenced another.

Eight paths and an error covariance were added to the model and seven paths were subsequently dropped due to nonsignificance (Figure 4.4). A path from SAT scores to instructor clarity, which was dropped in the intermediate model due to nonsignificance, was reintroduced as suggested by the re-estimated modification indices and consistent with the initial model. Paths were added from instructor interaction to instructor clarity and from interaction to participation in co-curricular activities. The inclusion of both paths is easily supported if one believes that instructor interaction with students influences how students perceive the clarity of instruction (e.g., Are assignments clearly explained? Are expectations clear?) and that when faculty interact with students, they encourage participation in appropriate co-curricular activities. Two additional paths were linked to instructor interaction, one going to group skills and one coming from group skills. The path from instructor interaction to group skills was part of the originally specified model (see Figure 3.1) that initially appeared to reflect a nonsignificant relationship, but reemerged as significant during the modification process. This path in combination with the new path from group skills to instructor interaction reflects the hypothesis that students who perceive their group skills to be high are more likely to interact with faculty and that faculty are more likely to interact with students who are good team members, rather than students who tend to or prefer to work alone.

Similarly, the modification indices suggested a path from collaborative learning to instructor interaction. This relationship has merit if one keeps in mind that one component of the collaborative learning variable is doing things that require students to be active participants in the teaching and learning process. Given this aspect of collaborative learning, the addition of this path suggests that such engagement leads to increased interaction with faculty.

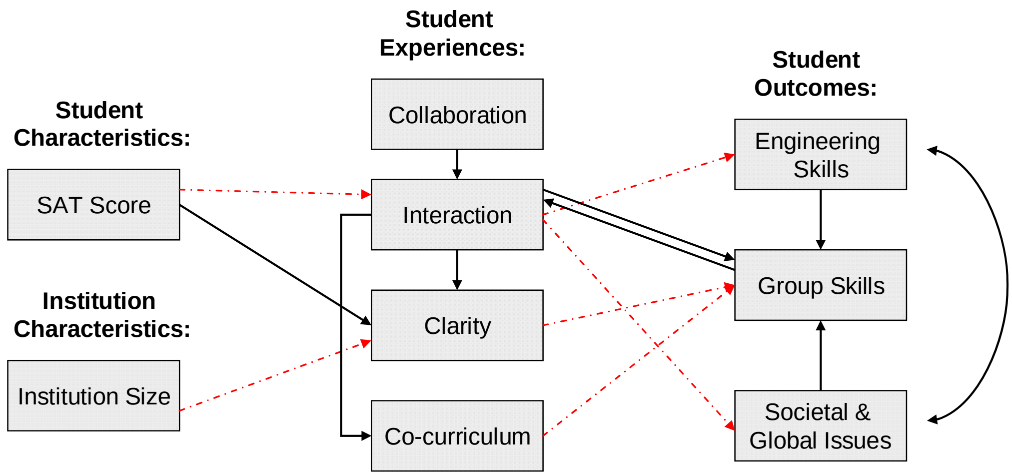

Figure 4.4: Changes to the Intermediate Model

Note: Straight black lines indicate an added path, red dashed lines indicate a deleted path, and a curved line indicates an added error covariance.

Although the variables assessing student learning originally were entered into the model as three distinct learning outcomes, the assumption that learning outcomes are not interrelated is overly simplistic. A path was added from engineering skills to group skills based on the premise that skilled students are more often called upon to assist their peers and that through this interrelationship, their group skills increase. A path was added from knowledge of societal and global issues to group skills under the hypothesis that knowledge of such issues will increase students' appreciation for collaborative work by acquainting them with complex issues that cross geographical and cultural boundaries and that are unlikely to be solved in isolation. Knowledge of such issues may encourage students to develop group skills. Lastly, the modification indices suggested the addition of a possible path from engineering skills to knowledge of global and societal issues. Recognizing the interrelationship of the outcomes, but unable to support conceptually the causal connection suggested by such a path, an error covariance was added instead, indicating that something outside of the model may be influencing this relationship.

Although model modification ended here in order to avoid over-fitting the model, future researchers may wish to explore the possibility of reciprocal relationships between the outcome variables. As engineering skills influence group skills, group skills may also influence engineering skills because students learn by teaching one another. Group skills may also influence knowledge of societal and global issues by giving students experience working in culturally heterogeneous settings, promoting understanding of other cultures and people.

With these adjustments, the model remains identified although the addition of reciprocal causation and an error covariance make it no longer recursive. The variables that make up the non-recursive portion of the model (interaction, group skills, engineering skills, and societal/global issues) can be viewed as a block that is identified using the rank and order conditions. The entire model is then identified using the block-recursive rule, in which the relationships between the identified blocks of endogenous variables are recursive, resulting in an identified model (Rigdon, 1995).

Overall Fit

The overall model fit statistics for the final re-specified model are strong, suggesting that the data fit the conceptual model (Figure 4.5). The chi-square statistics still indicate that the model should be rejected, as with the initial model, but this result was anticipated due to the large sample size and is thus not an adequate measure of fit (Table 4.7). The RMSEA is well below Byrne's (1998) recommended level of .05 for good fit and its 90 percent confidence interval is well within bounds (.012; .023). Further, the Akaiki Information Criterion (AIC) and the Consistent Akaiki Information Criterion (CAIC), indices used to compare non-nested models,[14] show dramatic improvement (decrease) in the final model.

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[14] The AIC takes model size into account, while the CAIC adjusts for sample size.

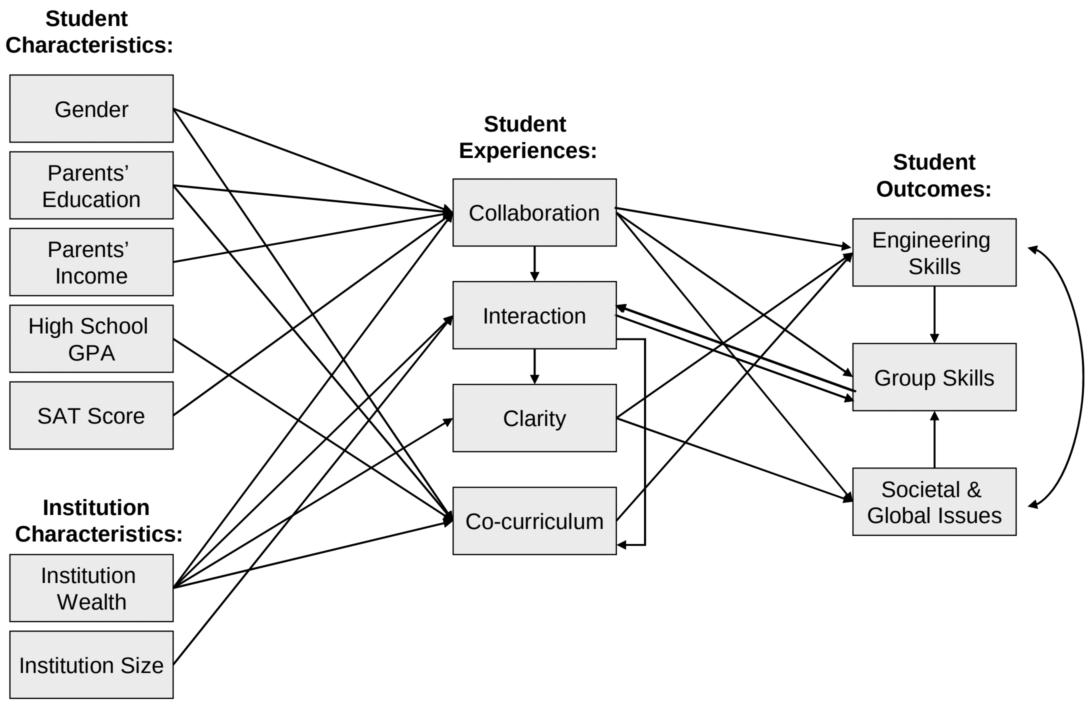


Figure 4.5: Final Model

Note: Straight lines indicate paths and the curved line indicates an error covariance.

Table 4.7: Selected Fit Indices for Final Model.

	Final model (df = 44)	**Intermediate Model (df = 46)**	**Initial Model (df = 33)**
Normal theory weighted least squares χ^2	265.27 (p = 0.0)	3893.89 (p = 0.0)	3819.41 (p = 0.0)
Satorra-Bentler χ^2	82.89 (p = 0.0)	1243.94 (p = 0.0)	1500.82 (p = 0.0)
Root mean-square error of approximation	.02	.10	.12
Normed fit index	.99	.87	.85
Comparative fit index	.99	.87	.85
Goodness-of-fit index	.99	.84	.85
Standardized root mean-square residual	.03	.12	.11
Akaike information criterion (AIC)	204.89	1361.94	1674.82
Consistent AIC	629.94	1773.05	2281.03

Component Fit

The component fit of the model is reasonable although the coefficients for are small. The directionality of the components is generally as hypothesized with female students having the advantage in collaborative learning and in co-curricular activities, and positive relationships between parents' education, family income, high school GPA and SAT scores with student experiences (Table 4.8). The negative relationship between SAT score and collaborative learning may reflect the fact that engineering students typically have higher SAT math than SAT verbal scores, so that their total SAT score is typically weighted towards math skills, and math is a traditionally non-collaborative subject area. Not surprisingly, larger schools fostered less instructor interaction but unexpectedly, institutional wealth was inversely related to collaborative learning, instructor interaction, and co-curricular activity. Although this relationship may appear counterintuitive, wealth in this sample is measured by the average salary of full professors and large, research oriented engineering programs tend to rank highly on this measure, to the detriment of teaching and student engagement. Pike, Smart, Kuh, and Hayek (2006) reported similar findings, with several measures of student engagement inversely related to status as a doctoral/research university.

The relationships between student experiences and student outcomes were positive (Figure 4.6), with the exception of instructor interaction and feedback with group skills. This inverse relationship is difficult to explain and deserves further attention. It may be that instructor feedback focuses on skills other than group skills or it may be that instructors that spend a great deal of time interacting with students assign less collaborative work, thereby inhibiting the development of group skills. However, the nature of the data is insufficient to test this or other hypotheses related to this relationship. Where significant, the relationships between student experiences, between student outcomes, and between student outcomes and experiences were all positive, reflecting beneficial relationships between these variables.

Table 4.8: Standardized Final Model Coefficients between Control Variables and Student Experiences

	Collaboration	**Instructor Interaction & Feedback**	**Instructor Clarity**	**Co-Curricular Participation**
Student characteristics				
Gender	-.13***			-.06**
Parents' education	.08**			04 [a]
Parents' income	.11**			
High school GPA				10[b]
SAT score	-.17***		.09***	
Institution characteristics				
Size		-.17***		
Wealth	-.05*	-.13***		-.05**

* p = .05, ** p =.01, *** p = .001
[a] p = .06
[b] p = .12

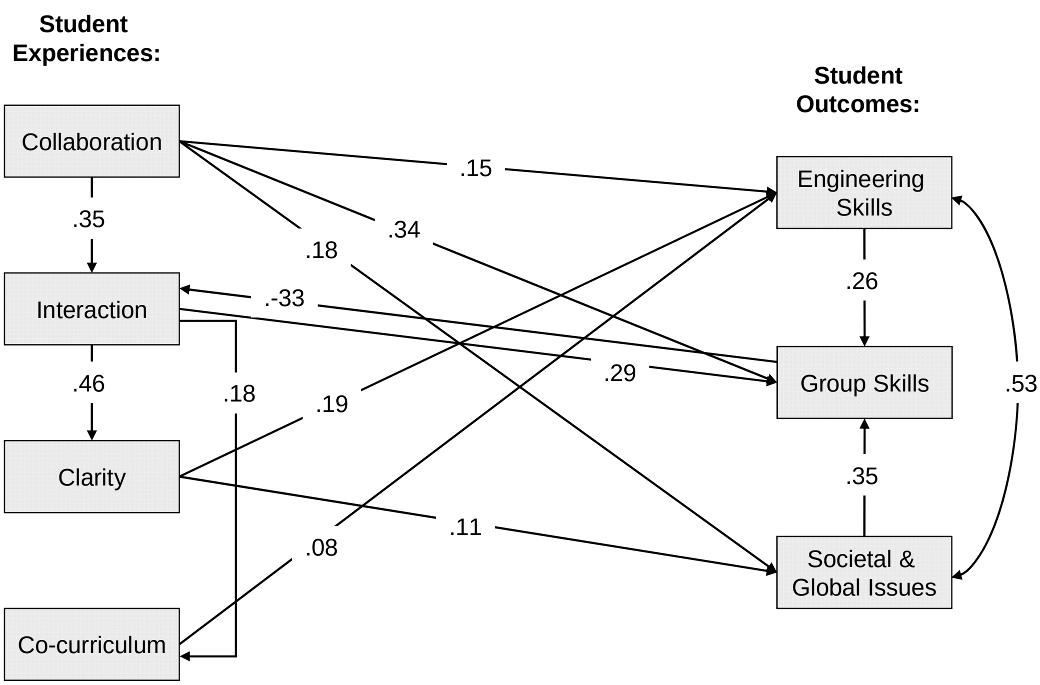


Figure 4.6: Standardized Final Model Coefficients between Student Experiences and Student Outcomes

The standardized error covariance between engineering skills and knowledge of societal and global issues was large (.53, standard error=.012), in comparison to most of the path coefficients, and significant (Figure 4.6). With the exception of high school GPA and parents' education to co-curriculum, the components are all significant at the .05-level, but the reduced R^2 values suggest that only very small amounts of variance are explained by the model (Table 4.9). Although the number of residuals greater than two was reduced from 32 in the initial model to 8 in the final model, and examination of the Q-plot indicated improvement in the model fit, the evidence suggests that further model development and testing is needed.

Table 4.9: Reduced R^2 Values for the Endogenous Variables in the Final Model

Dependent Variable	Reduced R^2
Collaboration	.058
Interaction	.061
Clarity	.013
Co-Curriculum	.023
Engineering Skills	.003
Group Skills	.008
Societal & Global Issues	.002

Path Models for High and Low-CI Programs

The multiple group analyses for the constrained and the unconstrained, or base, model resulted in reasonable overall model fit in each case (Table 4.10). Comparison of the models using the Satorra-Bentler corrected chi-square difference test indicated that the unconstrained model, in which the path coefficients were allowed to vary between the high- and low-CI models, provided significantly better overall model fit (corrected $\Delta\chi^2 = 40.67$, df = 26, $p < .05$), indicating that while the path model fits both groups, the nature of the relationships between variables differs. Table 4.11 presents a comparison of the path coefficients for both models, completely standardized on a common metric to enable comparison of the high and low model parameters.

Table 4.10: Selected Fit Indices for Constrained and Base Models

	Constrained (df = 114)	**Base Model (df = 88)**
Normal theory weighted least squares χ^2	361.34 (p =0.0)	318.89 (p = 0.0)
Satorra-Bentler χ^2	230.68 (p = 0.0)	185.31 (p = 0.0)
Root mean-square error of approximation	.03	.03
Normed fit index	.97	.98
Comparative fit index	.99	.99
Goodness-of-fit index	.98	.99
Standardized root mean-square residual	.04	.04

In both the high- and the low-CI models, the coefficients were typically significant to the same extent and similar in magnitude suggesting that despite the statistically significant difference when the paths were allowed to vary between the two groups, the differences are actually small. In this type of multiple group analysis, differences between the models' individual coefficients are not compared for statistical significance, so comparisons of individual relationships should be exploratory in nature, suggesting a basis for further research. The effects of student precollege characteristics, for example, appear to differ between the groups. The influence of parents' education on collaborative experiences and of high school GPA on participation in the co-curriculum are significant at the .01-level in the low-CI program group, but become nonsignificant in the high-CI group. In contrast, the opposite occurs in the relationship between parents' education and co-curriculum, which is nonsignificant for the low-CI group. The difference of greatest magnitude among these changes is that between high school GPA and participation in the co-curriculum. The magnitude of this difference (.07), in combination with the

Table 4.11: Comparison of the High- and Low-CI Groups Standardized Coefficients for all Relationships in the Path Model

Predictor variables	**Outcome Variable = Student Experiences**								**Outcome Variable = Student Outcomes**					
	Collaboration		**Interaction**		**Clarity**		**Co-curriculum**		**Engineering Skills**		**Group Skills**		**Global/Societal Issues**	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Student Characteristics														
Gender	-.10 [a]	-.15 [a]					-.11 [a]	-.05 [c]						
Parents' educ.	.06 [NS]	.09 [b]					.08 [b]	.03 [NS]						
Income	.13 [a]	.09 [a]												
HS GPA							.03 [NS]	.10 [a]						
SAT	-.13 [a]	-.19 [a]			.09 [a]	.09 [a]								
Institution Characteristics														
Size			-23 [a]	-.14 [a]										
Wealth	-.06 [NS]	-.03 [NS]	-.16 [a]	-.10 [a]			-.06 [c]	-.04 [NS]						
Student Experiences														
Collaboration			.39 [a]	.32 [a]					.17 [a]	.14 [a]	.34 [a]	.34 [a]	.19 [a]	.17 [a]
Interaction					.48 [a]	.44 [a]	.19 [a]	.17 [a]			-.28 [a]	-.36 [a]		
Clarity									.17 [a]	.20 [a]			.12 [a]	.10 [a]
Co-curriculum									.06 [c]	.09 [a]				
Student Outcomes														
Engineering Skills											.30 [a]	.24 [a]		
Group Skills			.27 [a]	.30 [a]										
Societal/Global Issues											.33 [a]	.36 [a]		

Note: Cells with no entry are not part of the path model.
[a] p = .001, [b] p =.01, [c] p = .05

change from a highly significant ($p < .001$) relationship in the low-CI group and a nonsignificant coefficient in the high-CI group, suggests that the high-CI programs are doing something to level the playing field between students with different levels of high school achievement.

The influence of institution size on faculty interaction and feedback showed the greatest difference in magnitude between the high- and low-groups of any of the paths. In both groups size was inversely and significantly ($p < .001$) related to student reports of instructor interaction and feedback, however, the coefficient for the high group was greater in magnitude (.09), suggesting that students in the high-CI programs felt the influence of institution size on the amount of instructor interaction and feedback that they received to a greater extent than their peers in low-CI programs. Contrary to expectation, however, the inverse relationship indicates that being at a large institution reduced interaction *more* for high-CI programs than for low. This finding may be related to the fact that high-CI programs are more likely to be found in smaller baccalaureate institutions, suggesting that students who choose these types of institutions are more negatively affected by increasing size than students who choose masters/research institutions.

As discussed in the re-specified model for all students, instructor interaction and feedback were negatively related to group skills. While both the high- and low-group models reflected this relationship, the magnitude of the coefficient for the high-CI group (-.28) indicated that the influence of interaction and feedback was less for this group than for the low-CI programs (-.36). Another of the largest difference in coefficient magnitude occurred in the path between the engineering skills and group skills outcomes. This path was introduced into the re-specified model on the assumption that highly-skilled students would be encouraged and expected to assist other students in collaborative efforts, thereby increasing their group skills. In the high-CI group, the coefficient for this path was larger, suggesting that this influence is felt more strongly in high-CI programs.

Overall, the differences between the path coefficients in the high- and low-CI groups were mixed. Net of the influence of student pre-college characteristics and institutional characteristics, the magnitude of the paths in the high-CI program model were greater for eight of the modeled paths, were smaller for four, and were unchanged for one (Table 4.12). This suggests that high-CI programs develop stronger relationships between student experiences and student outcomes, and interrelationships between experiences and between outcomes.

Table 4.12: Summary of Differences between the High- and Low-CI Path Coefficients

Path	Coefficient more positive in: High-CI Model	Coefficient more positive in: Low-CI Model
Collaboration		
→ Instructor interaction and feedback	✓	
→ Engineering skills	✓	
→ Group skills	Same	Same
→ Knowledge of global & societal issues	✓	
Instructor interaction and feedback		
→ Instructor organization and clarity	✓	
→ Co-curriculum	✓	
→ Group skills	✓	
Instructor organization and clarity		
→ Engineering skills		✓
→ Knowledge of global & societal issues	✓	
Co-curriculum		
→ Engineering skills		✓
Engineering skills		
→ Group skills	✓	
Group skills		
→ Instructor interaction and feedback		✓
Knowledge of societal and global issues		
→ Group skills		✓

Limitations

Limitations of the Study

This study takes advantage of an existing dataset which provided a large sample that included reports from both students and faculty. There are, however, threats to internal validity. It was not possible to manipulate the level of program continuous improvement effort and randomly assign students to these programs in order to demonstrate causality (Krathwohl, 2004). In addition, despite the use of a number of control variables, respondents may still not be functionally equivalent and weighting of data to simulate representativeness may obscure real differences between respondents and nonrespondents. Further, a strong case for causality requires the establishment of time precedence where cause precedes effect (Kline, 2005). Despite the use of a causal model, claims of a causal connection between continuous improvement efforts and improved student learning cannot be made with cross-sectional data.

An additional limitation is the use self-reported data for student learning. Although direct measures of learning, such as a standardized, objective test, would be preferable, even when available, such assessments are time-consuming and costly to collect. Moreover, there is no widely used standardized test of the engineering learning outcomes specified by the EC2000 accreditation criteria (Lattuca et al., 2006a). Fortunately, research indicates that self-reports of learning can provide a reasonable estimation of actual learning (Anaya, 1999; Kuh, Kinzie, Schuh, Whitt, & Associates, 2005; Laing, Swayer, & Noble, 1989; Pace, 1985; Pike, 1995). The reliability of the dataset is further supported because it meets the criteria outlined by Kuh et al. (2005) and Pike (1995) for the use of self-reports: the information is known to the respondents, the questions are unambiguous and refer to recent activities, the respondents take the questions seriously, and responding has no adverse consequences nor does it encourage socially desirable, rather than truthful, answers. As a result, one can reasonably conclude that the student learning outcomes revealed in the data are reasonable proxies for more objective measures of learning.

With the exception of one open-ended question on the program chair survey, the instruments consist entirely of closed-ended items. Although this strategy allows for a greater number of questions, provides uniformity, and facilitates data analysis, it does have disadvantages. Close-ended questions are subject to the influence of the investigator, and reader misinterpretations cannot be determined from responses. Further, close-ended items intentionally allow only a limited variety of responses.

Finally, the framework itself poses some limitations. One immediate cause for concern is the failure to account for outside influences such as the effects of the engineering industry and changes in curriculum other than those generated by continuous improvement. As a conceptual framework it is necessarily a simplification of reality, however whether it is an oversimplification that ignores key influences remains to be seen. This project will explore explanatory and inferential power of this framework and the influence of continuous improvement on the relationships it posits.

Limitations of the Dataset

Because of its size and scope, the *Engineering Change* dataset offers a unique opportunity to explore complex models of the student college experience. As many researchers have found however, secondary data analysis often has inherent limitations. Survey items seldom ask exactly the questions you wish to ask and often the metrics do not fit the requirements to apply the desired statistical tools. Further, survey data, although used to facilitate large-scale research studies in which individual interviews or formal experimental methods are not realistic alternatives, can pose a number of unique challenges to empirical researchers.

The *Engineering Change* study, as its name implies, investigated changes in engineering education over time. Because it was a cross-sectional, rather than longitudinal study, the faculty survey asked respondents to answer various questions in relation to changes over time. For example, faculty were asked to rate their participation in seminars or workshop on teaching and learning compared to five years ago (less, same, more) and to report whether they had participated in those activities within the past 12 months (yes or no). All of the items used in the instructional development and research to improve undergraduate education scales followed this format. For the purposes of this study, a more desirable metric for rating faculty participation in these activities would have reflected the amount or number of times faculty spend per year on average in such activities. While a faculty member might report that he/she participated in a given activity “more” than compared to five years ago this data may be difficult to interpret.

Ordinal responses to questions that are inherently continuous, such as the respondents’ age (e.g., 18-24 yrs., 25-30 yrs. etc.) are often used even when a simple number could be reported to minimize reporting error (e.g., the potential of misreading a paper-and-pencil survey) and to reduce data. For example, pre-college academic ability is a well-documented and significant predictor in models of student outcomes (Pascarella & Terenzini, 1991, 2005). Although inherently continuous in nature, it is a construct that is often measured in a categorical fashion. In the model, two important variables are used to control for student pre-college ability: high school GPA and SAT scores. While SAT scores were reported in raw numbers, high school GPA was reported as an ordinal variable (6 pt. scale, where 6 = 3.50 - 4.00 . . . 1 = below 1.49), greatly reducing the amount of potential variance among a group of high achieving students on an important control variable, limiting the explanatory power of this variable in the model. Such ordinal responses, however, are often used in survey questions to maximize responses on questions that may be sensitive, such as income, SAT score, and age, because respondents are more likely to respond if given a selection of ranges than if asked to report an exact number (Dillman, 2000).

In order to collect large samples that allow for inference to a population, surveys are generally designed to be taken by participants in the least amount of time necessary to provide the key information desired (Dillman, 2000; Kalton, 1983). Survey responses therefore are most often limited to Likert-type scales with a small number of response options (typically five, but sometimes more or fewer). While useful for gathering large samples, such responses present analytical challenges. First and foremost, although treated as such in many studies, ordinal variables are not and should not be treated as continuous variables (Kline, 2005; Tabachnick & Fidell, 2001). The nature and distribution of continuous and ordinal variables are inherently different. This issue is addressed in these analyses by using only composite endogenous variables (aggregates of survey items that provide a continuous measure). What this approach cannot correct for is the fact that while the Likert-type scales that form the composite variables are ordinal (there is a clear order to the categories), most statistical analyses, included those used herein, treat them as interval, assuming that the spacing between variables (e.g., between "strongly agree" and "agree" and between "disagree" and "strongly disagree") is even. Treating an ordinal variable as an interval one may result in distorted calculations of correlations, the foundation of all regression-based statistical techniques (Mayer, 1971). Despite this limitation, survey researchers argue that the advantages of treating Likert-type measures as interval far outweigh the disadvantages (O'Sullivan & Rassel, 1995).

Differentiating and Validating Continuous Improvement Clusters

Although the finding that doctoral institutions were less likely than non-doctoral institutions to exhibit high continuous improvement levels was not unexpected, broad generalizations based on these findings should be undertaken with caution. The terms "doctoral" and "non-doctoral" paint institutions in the broadest possible brush-strokes. Institutional and faculty culture vary immensely among institutions in these two categories. Subsequently, inferences made at this level should not be applied to individual institutions without careful evaluation of that institution's culture. Previous studies have shown institutional type to have a relatively minor influence on curriculum planning and concluded that discipline is the dominant factor (Stark, 2000; Stark, Lowther, Bentley, & Martens, 1990; Stark, Lowther, Bentley, Ryan et al., 1990; Stark & Shaw, 1990). These studies, however, emerged from the National Center for Research to Improve Postsecondary Teaching and Learning which was dedicated to the study of undergraduate education in teaching institutions. As a result, research universities and their faculty are not represented, nor is engineering included in the academic fields represented in the work of Stark and her colleagues. This study expands on previous work that finds discipline to be the dominant factor in curriculum planning by delving within a single disciplinary area to tease out secondary influences that are overshadowed when the practices of faculty in broadly disparate disciplines are compared.

Although these results support the argument that faculty support for continuous improvement is an important predictor of faculty participation in continuous improvement, the possibility that activities actually predict attitudes cannot be discounted because of the cross-sectional nature of this data. In order to demonstrate a causal link, a research design that incorporates time precedence would be required. Despite this drawback, the evidence for attitudes as determinants of activities provided by this study, in combination with previous research findings supporting this hypothesis, is strong. Future research in this area should make use of longitudinal data to provide a definitive answer to this chicken-and-egg question.

Limitations of Single-Level Modeling

Although the focus of this study was on a program-level influence (CI) on students, the final analyses in this study modeled this influence only at the student-level. The findings of the hierarchical model tested did not indicate sufficient variance in outcomes at the program-level to warrant multilevel modeling, with engineering program as level-2. This mode of analysis, however, should not be abandoned entirely. Given the relatively homogenous nature of most engineering programs, the adherence to a common set of learning outcomes designated by ABET, and the fact that the sample contained seniors only, who presumably had all attained a relatively high level of engineering skill, little variance existed in the data to be explained at any level, much less at multiple levels. Engineering departments vary in their focus, their culture, and their climate. These differences are found not only between institutions, but also between disciplines within institutions. Although deemed inappropriate for further development in this study, future research should not ignore the multilevel nature of the influences on student while in college. Although not the focus of this study, future researchers may wish to expand the hierarchical model to a third-level in order to consider institutional effects separately.

Limitations of the Path Analyses

Resulting from Model Simplification

While the primary advantage of path analysis over traditional regression techniques is the ability to test increasingly complex models, the number of variables and paths that can be included is limited. In order to form a testable model, the first step was to limit the number of variables. The dataset contained a large number of potential control variables shown in previous research or hypothesized to potentially influence student experiences and outcomes. Many were used in the model, but several were eliminated: student age, status as a native or transfer student, citizenship status, student self-evaluation of their preparation for college, engineering discipline, institutional participation in an NSF coalition, EC2000 adoption status, institutional control (public or private), and institution Carnegie Classification. Preliminary regression analyses for both the high- and low-CI groups (see Appendix F for results) indicated the majority of these variables – student age, transfer status, self-reported preparedness, engineering discipline, NSF coalition, EC2000 adoption status, and institutional control – did not significantly influence student learning outcomes. Although citizenship status did emerge as a potentially significant predictor, it is not a critical or often-used control variable and it was eliminated from the model. While the elimination of these control variables from the model does leave open the possibility that these student pre-college and institutional characteristics do influence student experiences and outcomes, the results of the preliminary regressions indicate that their elimination was justified. As modeling technology and methods increase, the inclusion of these variables in future models should be considered.

In addition, the number of control variables, individual race categories were collapsed into a single dichotomous variable where 1 = underrepresented minority (Black/African American, Hispanic/Latino/a, American Indian/Alaskan Native, Hawaiian/Pacific Islander) and 0

= not an underrepresented minority (White or Asian/Asian American). The reduction of seven variables into a single variable was a necessary simplification of the model, but it fails to acknowledge the potential for vastly different experiences of students of different races and ethnicities. While recognizing that the college experience of these groups differs in many important aspects, preliminary analyses indicated that the individual race categories were most often nonsignificant influences on student outcomes. Further, the purpose of using race as a control variable in the model is to net out the influence of the majority versus minority experiences rather than to explore potential differences in the model by racial/ethnic category.

Another limitation caused by the need to simplify the model was the exclusion of the measurement model that is part of a full structural equation (SEM) model. While path analysis, as demonstrated in these analysis, is an SEM technique, a full structural equation model also includes the measurement model (i.e., it incorporates the factor analysis into the model). Had a full structural equation model been tested, each of the variables that were scales, for example, continuous curriculum planning, would have been represented as latent constructs in the model, with the constituent items making up the scales, also represented with their factor. In treating the scale variables as observed variables, the path approach fails to recognize their latent nature and further simplifies reality to accommodate statistics.

Resulting from Analytical Compromises

Path analysis uses covariance or correlation matrices as the basis for analysis. The most commonly understood and used correlation is the Pearson's, however in models with a mix of continuous and ordinal endogenous (Y) variables, the use of correlation matrices based on Pearson's will be biased. Further, ordinal and dichotomous[15] variables are not normally distributed, violating a basic assumption of maximum likelihood estimation, the estimation

[15] The control variables gender and minority are dichotomous.

method used in most path models. For this reason, when the data include a mix of continuous, ordinal, and dichotomous variables, Jöreskog (1990) recommends using a matrix of polychoric and polyserial correlations[16] with weighted least squares estimation. This approach is recommended in order to eliminate the biases associated with misusing the standard correlation/covariance matrices and avoid misestimation of the standard errors caused by non-normality.

The initially proposed path model proposed included a mix of dichotomous, ordinal, and continuous exogenous variables, and a mix of ordinal and continuous endogenous variables. While the presence of dichotomous and ordinal exogenous (X) variables is not cause for concern (P.W. Lei, personal communication, November 28, 2007), the mix of ordinal and continuous endogenous (Y) variables necessitates the approach recommended by Jöreskog. Preliminary attempts to develop a model using that approach, however, were unstable and failed to produce results. In order to eliminate the need for the use of the polychoric/polyserial matrix, the three non-continuous endogenous variables, time spent in internships/coops, time spent in design competition, and participation in professional societies, were standardized and summed to create the single continuous variable, co-curriculum, which replaced the three individual out-of-class experience variables in the path model. Further, robust maximum likelihood was used to accommodate the non-normality in the data, replacing weighted least squares as the estimation method. Only under these conditions would the model run.

While the steps taken to simplify the model were necessary, they eliminated the option to consider the specific influences of internships/coops, design competitions, and professional society participation on the educational experience and outcomes of engineering students. Previous findings suggest that these experiences can have significant influences on student

[16] Polychoric is used when both variables are dichotomous/ordinal, and polyserial when correlating a continuous and a dichotomous or ordinal variable.

learning outcomes (Lattuca et al., 2006a) and combining them into a single co-curricular index variable eliminated the opportunity to further explore their individual influences within the model. The creation of the co-curricular variable does provide, however, the opportunity to consider the relationship the co-curriculum, more broadly defined, with other educational experiences and learning outcomes, and prevented the elimination of the out-of-class experience from the model. Future research should consider the influence of these experiences individually.

Chapter 5

DISCUSSION, CONCLUSIONS, and IMPLICATIONS

Restatement of the Problem

In an era of public skepticism, American higher education institutions are increasingly pressed to demonstrate their commitment to, and success in, educating undergraduate students. Faced with increasing concern that peer review through accreditation, the primary higher educational quality control mechanism used in the United States, is no longer sufficient to guarantee the long-held superiority of our system of higher education, accreditors have incorporated continuous improvement principles into their criteria to stimulate ongoing quality improvement. Engineering accreditation has taken this approach the furthest, not only incorporating continuous improvement principles into its criteria but also establishing a set of required learning outcomes for all programs and commissioning a comprehensive, national study designed to assess the influence of these and other changes to their criteria (Lattuca et al., 2006a). Using the dataset developed for that project, this study was able to explore the influence of continuous improvement activities on undergraduate students by addressing three research questions: 1) Do programs differ measurably on these continuous improvement variables, 2) Do continuous improvement activities directly affect engineering student learning outcomes, and 3) Does continuous improvement level influence the nature of the relationships between student pre-college characteristics, institutional characteristics, student experiences, and student outcomes?

Project analyses occurred in three phases. A cluster analysis grouped programs based on their continuous improvement activity level. A hierarchical model parsed out the variance in student outcomes due to student-level differences and to program-level differences, tested the role of continuous improvement level as a program-level predictor of student outcomes, and determined whether a multi-level model was necessary. Finally, a series of path analysis models explored the validity of the conceptual framework and the influence of continuous improvement level on the relationships it posits. Each analysis contributes to our understanding of continuous improvement in academic programs, and in this chapter I discuss each individually. As a whole, however, these analyses illustrate the validity of continuous improvement level as a differentiating factor among academic programs and as one that is positively related to many aspects of students' college experiences and learning. These findings have a number of implications for practice, policy, theory-building, and future research.

Discussion and Conclusions

Continuous Improvement Level as a Program Differentiator

The purpose of the cluster analysis was two-fold: 1) to determine whether engineering programs could be differentiated meaningfully based on continuous improvement activities, including a continuous curriculum planning construct (Briggs et al., 2003) and measures of faculty participation in assessment and professional development activities, and 2) to test the hypothesis that faculty attitudes influence the level of continuous improvement activity in departments. While cluster analysis can be a useful tool for grouping cases within a sample or population, its utility depends on the ability of researchers to find meaning in the groups it identifies. In this case, within the 142 engineering programs in the sample, cluster analysis identified a group of programs with high levels of commitment to continuous improvement practices and a group with lower levels. The differences between the high and low group on each of the continuous improvement variables, while small, were statistically significant, supporting the utility of each of the continuous improvement measures in differentiating programs. Further, faculty enthusiasm for assessment, the variable identified as a theoretical predictor of continuous improvement level, was a significant predictor of group membership; supporting the argument that faculty buy-in is an important factor in continuous improvement implementation.

Measuring Continuous Improvement

Validating Briggs et al.'s Continuous Curriculum Planning Criteria

Following the suggestion of Briggs and her colleagues (Briggs et al., 2003) for further validation of continuous curriculum planning criteria, the two-cluster solution presented in this paper tested the application of the criteria to differentiate a varied, and national, sample of engineering programs. In the *Engineering Change* study, Lattuca et al. (2006) validated a large set of survey items, including those related to continuous curriculum planning, through a rigorous instrument development process involving engineering faculty, students, industry representatives, and assessment experts. The faculty and student surveys were then pilot tested with engineering faculty and students at The Pennsylvania State University. This process verified that the continuous curriculum planning items were "understandable and meaningful to the practitioners whose activities and beliefs they describe[d]" (Briggs et al., 2003, p. 384). Based on the cluster analysis and subsequent ad-hoc tests on each of the continuous improvement variables of the differences between programs identified as high- and low-CI, the engineering programs in the sample were distinguishable based on the continuous curriculum planning scale developed for the *Engineering Change* study. These results support the validity and stability of the continuous curriculum planning criteria and their utility in identifying continuous curriculum planning departments.

Expanding the Continuous Curriculum Planning Model

The continuous curriculum planning construct introduced by Briggs et al. (2003) offers researchers and evaluators one approach to assessing the adoption of continuous improvement activities by academic programs. Used alone, however, this scale, as conceived by Briggs et al., and as applied in the *Engineering Change* study, does not fully incorporate all of the principles of continuous improvement as defined in this study. Assessment is addressed in only one item of this eight-item continuous curriculum planning scale, and human resource development is not addressed at all in either the *Engineering Change* scale or in the construct as originally described by Briggs et al. (2003). This study expanded the continuous curriculum planning model by incorporating these principles into the criterion used to distinguish academic programs.

Criterion four of the continuous curriculum planning construct, Use of Evaluation for Adaptive Change, is perhaps most central to continuous improvement. Continuous improvement demands that efforts be data-driven and not just change for the sake of change or based on anecdote or beliefs. In the *Engineering Change* faculty survey, the items that made up the Continuous Curriculum Planning scale focused primarily on frequency of curriculum planning and faculty participation in curricular planning, for example, “Faculty in my program periodically review the program mission and objectives,” and “Faculty in my program collaborate on curriculum development and revision.” Evaluation is tapped only in a single item in this scale, “Curriculum decisions are usually based on opinions rather than data.” While this item captures faculty beliefs about the use of data to drive curriculum decisions, it does not measure faculty participation in data collection. If a continuous improvement philosophy has been adopted by faculty members, they should view themselves as part of the process and participate by collecting, evaluating, and interpreting data on curricular outcomes. Even in departments with the resources to hire a dedicated "assessment person," this individual is not in the classroom. It remains the responsibility of faculty members, primarily, to assess the progress of their students.

In order to build a more complete picture of faculty commitment to improvement from Brigg's et al.'s (2003) criteria, an additional item was included in the analysis which directly asked faculty to rate their "personal effort in student outcomes assessment." This item reflects an important dimension continuous improvement which was not part of the continuous curriculum planning scale developed for the *Engineering Change* study, but was included elsewhere in the survey. As found with continuous curriculum planning, the high- and low-CI programs differed significantly with regard to faculty self-reports of personal participation in outcomes-based assessment, with faculty in the high group more likely to report that their level of participation was "moderate," and faculty in the low group more often reporting that their participation was at "some" lower level than "moderate" on the survey scale. Despite the strong emphasis on outcomes-based accreditation in the ABET standards, as well as the focus on outcomes-assessment in higher education more broadly over the past decade, it appears that faculty are either not all on board or that many are supportive but not actively contributing to assessment efforts. In a large department with many faculty members, a critical mass of faculty may be all that is needed to support continuous improvement. In smaller departments, however, this may be problematic.

While the criteria outlined by Briggs et al. (2003) capture a number of important aspects of a programs' continuous curriculum planning processes, they do not include human resource development, another aspect of continuous improvement captured in Lattuca et al.'s (2006) data. Continuous improvement, as an organizational philosophy, stresses the need for ongoing education and training in order to respond ever-changing missions and processes (Freed et al., 1994). Consequently, another expression of a continuous improvement faculty culture is the participation of faculty in professional development activities related to instructional development and projects to improve undergraduate education. Because engineering faculty often lack training in curriculum development (Wankat et al., 2002), participation in professional development activities that focus on assessment, course development, and course improvement can be an indicator of commitment to continuous improvement.

Not surprisingly, given doctoral faculty focus on disciplinary specialization and recognition rather than development as a teacher (Austin, 1990), the high- and low-CI groups differed significantly; faculty in the high-CI group were more likely to report increased participation in instructional development activities and efforts to improve undergraduate education over the last five years. In both the high- and low-CI groups, faculty members were most likely to report that they made no changes in their professional development activities. Although this variable reveals changes over time in professional development activities, it does not reveal a faculty member's actual level of participation in these activities. It is possible that some faculty reported no increases over the previous five years because they have been participating in professional development and educational improvement projects at a relatively high level throughout their careers, or at least for longer than five years. While, this limitation should be noted, it seems reasonable in most cases to presume that faculty who report increases in their efforts at professional development related to teaching and improving undergraduate education are typically making greater efforts in theses areas than their peers who report no such increases.

Of the survey items that make up the two professional development scales related to improving teaching and learning (instructional development and participation in projects to improve undergraduate education), faculty members[17] were most likely to report that they participated in activities to gain content knowledge (75%). Fewer faculty members reported that

[17] These numbers are based on all faculty respondents in the *Engineering Change* database, rather than the sub-sample selected for the program-level analyses reported in this study.

they participated in activities to improve classroom instruction, for example, seminars or workshops on assessing student learning (30%), using the services of an on-campus instructional center (36%), or participating in a project to improve undergraduate education (48%). These results are consistent with findings that discipline is the dominant influence on faculty course planning in both introductory and advanced courses and this often translates to a focus on course content rather than pedagogy (Stark, 2000; Stark, Lowther, Bentley, & Martens, 1990; Stark & Shaw, 1990). These results suggest that despite the focus of accreditors on improving the quality of undergraduate education in a holistic way – by 1) establishing specific learning objectives, 2) developing curricular coherence by focusing on these outcomes, and 3) improving undergraduate teaching – it appears that faculty continue to focus primarily on content knowledge.

Despite the slight variations in the data, the cluster analysis successfully differentiated engineering programs based on several continuous improvement measures, including a scale variable based on Briggs et al.'s continuous curriculum planning criteria. These results support the hypothesis that significant variation exists among programs in these areas and contribute to the development of a more comprehensive set of measures for assessing the continuous improvement activities of academic programs (Table 5.1). These measures can provide faculty, administrators, and accreditors seeking to create or define a continuous improvement program with valuable benchmarks for achievement.

Table 5.1: Proposed Measures of Continuous Improvement

1. Continuous Curriculum Planning
2. Participation in Assessment
3. Instructional Development
4. Projects to Improve Undergraduate Education

The Divide between High- and Low-CI Programs

Initially, the *Engineering Change* (Lattuca et al., 2006a) research team hypothesized that adoption status (whether the EC2000 criteria were adopted prior to, during, or after their initial implementation) early, on-time, or deferred) would reflect of programs' preparedness to meet the EC2000 criteria. Volkwein and his colleagues (2006), however, found that this was not the case, or at least not by 2004 when the EC2000 criteria had been adopted by 76% of engineering programs in the *Engineering Change* sample. They speculated that when the EC2000 criteria were first implemented, programs that chose to defer accreditation under the new standards may have done so because they were behind those that did not, but by the time EC2000 became mandatory, many programs had "caught up" with the pack. These findings are supported by the results reported herein. Comparisons of the high- and low-CI program groups revealed no significant different between programs that underwent EC2000 accreditation early or on-time and those that deferred. While programs without continuous improvement processes in place may have chosen to defer adoption, when faculty were surveyed in 2003, levels of continuous improvement activities were not a distinguishing factor between programs of different adoption statuses.

In 1999, Birnbaum and Deshotels conducted a study to determine whether institutions of higher education were using continuous improvement. While the language of continuous improvement was and is pervasive in the academy, Birnbaum and Deshotels hypothesized that continuous improvement suffered from "virtual adoption," where institutions adopt the language of continuous improvement to align themselves with quality in the public perception, but neglect to incorporate continuous improvement activities into the organizational fabric. They concluded that many prior estimates of the pervasiveness of continuous improvement in higher education were overly generous and that in fact, only a relatively small number of institutions (approximately 13%), were truly implementing its tenets. What they did find was that public institutions were more likely to have adopted continuous improvement than private ones. They suggested that this might be the case because public institutions face more external pressures, from state legislatures for example, than private institutions.

In contrast, this study found high-CI programs to be equally likely to be located in private and public schools. The context of accreditation in engineering, however, is important. ABET accreditation is one of the dominant external pressures on engineering programs. Ninety-six percent of all engineering programs in the United States are ABET-accredited, and although not all administrators and faculty are fully supportive of ABET's criteria, accreditation is a necessary seal of approval for the vast majority of programs. Moreover, many states require graduation from an accredited engineering program for professional licensure, as do many professional certification bodies (ABET, 2007). Because of these requirements, ABET accreditation criteria are a critical influence on engineering programs and this influence is felt equally by institutions, regardless of their public or private control.

The dividing line between high- and low-CI programs in engineering appears to be institutional type. In her study of introductory course planning, Stark (2000) concluded that "The type of college is a minor influence compared to the extensive influence of the discipline;" however she noted that programs requiring specialized accreditation may feel more external influence on course planning than is generally the case (p. 430). Stark's conclusion was based on a wide-scale survey of faculty in teaching institutions that did not include doctoral institutions (as defined by current Carnegie classification). Influences on individual course planning may also differ somewhat from those on curriculum planning and influences on individual faculty as they plan courses may also differ from those acting on groups of faculty who are planning or revising program curricula. The results of this study suggest that within engineering, where external influence is high, subdisciplinary differences (e.g., between aerospace and chemical engineering) recede and institutional type emerges to play a significant role in curriculum planning. It may also be the case that that local conditions, including external influences, influence programs more, or differently, than do individual courses.

Many aspects of an institution, including size, disciplinary breadth, and research involvement, influence its placement in the Carnegie Classification system (McCormick & Zhao, 2005). All of these characteristics are determined, in part, by an institution's mission - its *raison d'être*. In the condensed Carnegie typology followed in this study, institutions were broadly classified into doctoral, master's, and bachelor's/special.[18] Although each institution in the study is unique, the amount of emphasis each places on research and/or teaching differentiates Carnegie groups, with doctoral institutions placing heavy emphasis on their research mission and non-doctoral institutions focusing more on teaching. Reporting on results from the *National Survey of Postsecondary Faculty*, Cataldi, Fahimi, and Zimbler (2005) found that doctoral faculty spent more time on research and less time on teaching, had fewer classroom contact hours, were less likely to consider teaching their principle activity, and were more likely to consider research to be their primary activity, than their non-doctoral counterparts. Because faculty members at doctoral institutions are less involved in teaching activities, they may also feel less directly involved in institutional effectiveness activities. Faculty that are not involved in institutional effectiveness activities, such as continuous improvement, are less likely to be supportive of such activities (Welsh & Metcalf, 2003).

Differences in teaching and research orientation are a critical factor in faculty support for assessment (Peterson, Einarson, Trice, & Nicholas, 1997), a key component of continuous improvement-orientation as defined in this study. In addition, research has shown that

[18] Institutions classified as Research Extensive and Research Intensive by the Carnegie system were included in the doctoral category; Master's Colleges and Universities were included in the master's category; and Baccalaureate Colleges and Special Focus Institutions were included in the bachelor's/special category. Special focus institutions are those with unique missions, such as the U.S. Military Academy at West Point.

institutional type influences how institutions respond to external pressure for assessment (Ewell, 1988). The result of this study suggest that even in a field with strong ties to external groups like employers and strong accreditation pressures, non-doctoral institutions may be more responsive to such pressures than doctoral institutions. Differences between doctoral and non-doctoral institution faculty may explain why engineering programs in doctoral institutions are more likely to be in the low-CI group and engineering programs in non-doctoral institutions are more likely to be in the high-CI group.

The significance of faculty support for outcomes assessment, a proxy measure for faculty support of continuous improvement activities more generally, as a predictor of program continuous improvement level suggests that faculty buy-in is critical component of continuous improvement adoption in academic programs. While accreditors and other influential bodies may mandate activities such as outcomes assessment and ongoing, systematic curriculum evaluation and improvement, faculty participation in such activities may be guided by their belief in the efficacy of such activities and their view of the cost versus the benefit. Because the evidence presented here is correlational, an alternative interpretation of these results – that the relationship between faculty enthusiasm and continuous improvement activities is such that the *activities promote enthusiasm* – cannot be discounted. When faculty members participate in continuous improvement activities, whether by choice or mandate, these activities may increase faculty support for assessment because they may yield beneficial results. Previous studies, however, have concluded that failure to cultivate faculty support is a key factor in the failure of institutional improvement activities (Birnbaum, 2000; Seymour, 1992; Welsh & Metcalf, 2003). The findings of this study support that interpretation and suggest that in order to be successful, those wishing to implement continuous improvement and similar improvement activities must find ways to cultivate faculty support rather than relying solely on external mandates to accomplish their aims for organizational and cultural change.

Differentiating Student-Level and Program-Level Variance in Outcomes with Continuous Improvement Level as a Predictor

The results of hierarchical linear modeling revealed that program-level variance in student outcomes, while statistically significant, was small. Only two percent of the variance in engineering skills and societal and global issues and three percent of group skills occurred between programs. These results indicate that a two-level model separating student-level and program-level variance is unlikely to add substantially to our understanding of student-level outcomes and that a student-level model is indicated. These results do not suggest that the program has no influence. Student experiences, for example, were not included in this model due to the limitations of HLM regarding mediating variables and these variables are well-known to have substantial influence on student learning (Lattuca et al., 2006a; Pascarella & Terenzini, 1991, 2005). What this model does suggest, however, is that the influence of these experiences should be considered at the individual level, rather than at the program-level. The addition of students' pre-college characteristics as control variables improved the hierarchical model significantly, demonstrating the importance of taking into consideration the influence of these variables on student outcomes. As has been demonstrated time and time again, however, college students do not enter college as tabula rasae; who students are when they come to college significantly affects their learning.

Institution size and wealth, thought to potentially influence the academic culture at an institution and the learning experience it provides to students, were not significant in the model, confirming previous findings that such variables are often too far removed from students' experiences to effect directly student learning (Astin, 1993; Pascarella & Terenzini, 1991, 2005). Similarly, and likely for the same reason, continuous improvement level was not a significant predictor of any of the learning outcomes. From this finding we should not conclude that continuous improvement level has no influence on student learning, but rather that it is not a direct influence. Like institutional characteristics, continuous improvement level may influence the magnitude of the coefficients the conceptual model. Whether or not a program's faculty collectively adheres to continuous improvement practices may not directly influence a particular learning outcome, but it may influence students' in- and out-of-classroom experiences, *thereby* indirectly influencing student learning outcomes. Further, the effect of program continuous improvement level on the relationship between institutional and student characteristics, student experiences and student learning may differ for high- and low-CI program, indicating that continuous improvement level moderates the effects of student experience on outcomes. Because HLM is inadequate to explore such complex models and because it is unable to incorporate multiple, potentially interrelated, dependent variables, path analytic models were introduced in the final phase of analysis.

Modeling the Conceptual Framework

The starting point for the path models developed in this study was a conceptual framework which hypothesized a linear relationship between student pre-college and institutional control variables, faculty-CI culture, student college experiences, and student learning outcomes. Based on the findings of the HLM model that continuous improvement was not a direct predictor of student learning outcomes, this aspect of the model was removed from the path structure, but retained in the model using multiple group path analysis, with continuous improvement level determining the groups. In this way, two models were developed – one for high-CI programs and one for low-CI programs – and the indirect influence of continuous improvement level on learning outcomes as it affected the relationships between the control variables, student experiences, and student outcomes, could be examined.

Consistent with previous research applying the conceptual framework initially developed by Terenzini and Reason (Lattuca et al., 2006a; Terenzini & Reason, 2005), the initial path model contained only one-way paths between each set of variables (Figure 5.1). The conceptual model upon which this study was based is presented in a unidirectional, linear format and was tested by Lattuca et al. (2006) and Terenzini and Reason (2005) using standard linear regression methods. Although this framework, as translated in the analytical framework used herein, was used as a starting point for the path modeling, the relationships between the variables in the model are unlikely to be so simplistic. The use of path analysis presented an opportunity to go beyond the unidirectional model and consider potential feedback loops and interrelationships within the experience variables and within outcomes.

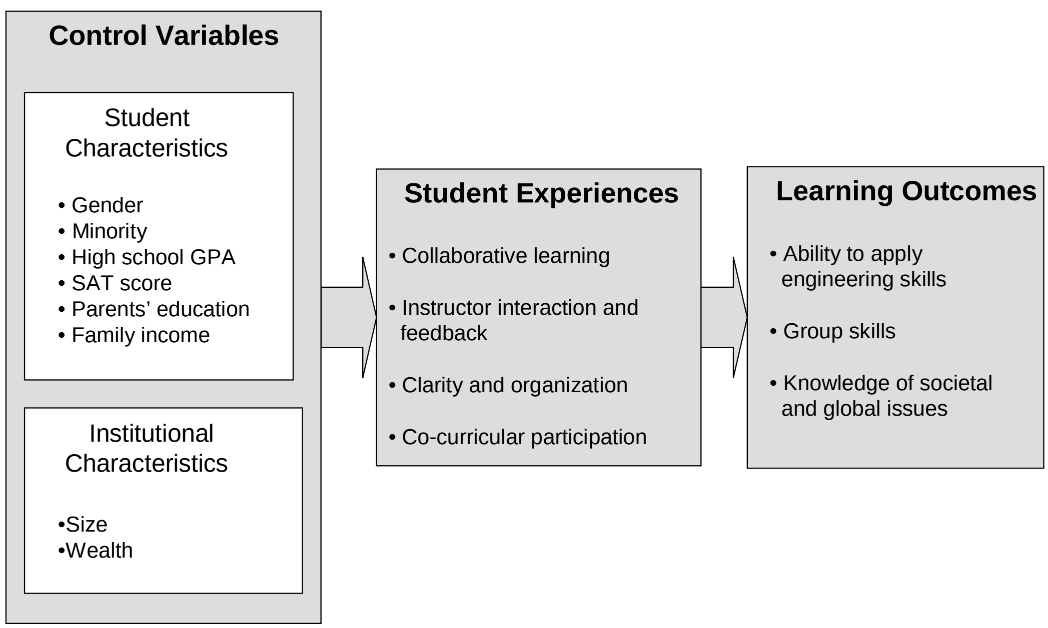


Figure 5.1: Analytical Framework Supporting the Initial Path Model

While path models offer many advances over traditional regression techniques, such models do have limitations. Even with a sample size of over 3,000 students, the number of paths (and subsequently the number of variables that can be incorporated into the model) is not limitless. Although program curricular emphases have been shown to be important predictors of student outcomes and variables reflecting these emphases were available in the *Engineering Change* database (Lattuca et al., 2006a), they were not included in the model due to limitations of the method. Simply put, such a large number of paths could not be estimated without enormous sample size, and even in that case, estimation techniques may fail. Because of this necessary simplification of reality and the use of a purely linear sequence of relationships, it was not surprising to find that sample data were not a good fit to the initial model.

Rethinking the Student Experience

Instructor Interaction and Feedback. The significant path from instructor interaction and feedback to group skills is consistent with the findings of numerous previous studies (see for example, Astin, 1993; Bjorklund et al., 2004; Cabrera & LaNasa, 2000). The introduction of a linkage between instructor interaction and feedback to instructor clarity and from instructor interaction to student participation in the co-curriculum other, however, offers a new wrinkle to this story. The influences of instructor interaction on student "outcomes," as defined in previous studies, suggests ways in which interaction might influence other student "experiences" as defined in this study. Bjorklund, Parente, and Sathianathan (2004), for example, found instructor interaction to be a significant predictor of occupational awareness and engineering competence. While both of these variables were defined as outcomes, which are traditionally viewed as the end-product of an educational process, it may be that outcomes like occupational awareness and engineering competence *influence* whether a student becomes involved in co-curricular activities such as design competitions and professional societies.

The introduction of a path from instructor interaction and feedback to instructor clarity is based on the premise that the more instructors interact with students, the more opportunities they will have for communicating with students, thereby increasing clarity. Although the higher education literature has separated instructor interaction and feedback and instructor clarity into separate student experiences (Cabrera et al., 2001; Lattuca et al., 2006a), research in the field of communications suggests that these are closely related variables. Sidelinger and McCroskey (1997) found that instructor immediacy (perception of small social distance between instructor and student) is positively related to students' perceptions of instructor clarity. Further, they found a significant positive relationship between students' perceptions of instructors as responsive and assertive and instructor clarity. These findings support the relationship between instructor interaction and instructor clarity posited in the re-specified model.

The addition of a path from the group skills outcome *to* instructor interaction and feedback introduces a non-recursive component to the model (i.e., the paths are no longer unidirectional in nature) and indicates a reciprocal relationship between these variables. The path coefficient from interaction to group skills is negative, but the path from group skills to interaction is positive. As surmised in the findings chapter, it may be that instructor feedback focuses on applied engineering skills and neglects to foster team building skills. Such neglect may convey to students that, although required in class, group work is not valued as highly as individual outcomes. Why then is the path from group work to instructor interaction and feedback positive? While focusing feedback on applied skills, instructors may be drawn to students who are team players and provide them with more feedback than their peers. Another possibility is that students with good group skills seek out interaction and feedback. This confusing relationship clearly suggests the need for further exploration of the relationship between these two variables.

Interrelationships between Outcomes Variables. The initial model outlined three independent outcomes – engineering skills, group skills, and knowledge of societal and global issues. The reality, however, appears to be far more complex than this. The addition of paths from engineering skills and from societal and global issues to group skills suggests two ways in which the group skills outcome may be developed via other learning outcomes. In their study of student learning in group projects, Colbeck, Campbell, and Bjorklund (2000) found that students consider the abilities and work ethic of their peers when allowed to choose group project members. “Slackers” were avoided, while students with the best technical skills often emerged as project leaders. Students’ engineering skills may determine both their role in group projects and their likelihood of working with similarly capable and equally motivated peers, an important aspect of positive group functioning (Bacon, Stewart, & Silver, 1999). Thereby their skill level may influence their group interactions, increase the likelihood that they will be asked to join groups they have worked with before, and positively influence both their perceptions of the nature of group work and their own group skills.

The addition of a path from knowledge of societal and global issues to group skills reflects the interconnection between globalization and collaboration in the engineering world. Nowhere is this more apparent than in the National Academy of Engineering’s 2004 report, *The engineer of 2020: Visions of engineering in the new century*: “The economy in which we [engineers] will work will be strongly influenced by the global marketplace for engineering services, a growing need for interdisciplinary and system-based approaches…and an increasingly diverse talent pool” (p. 4). If, as the Academy recommends, our engineering curricula take a systems approach that addresses the global and interdisciplinary context of many engineering problems, students should subsequently develop a greater appreciation for the diversity of skills and backgrounds needed to address the problems that face our world today.

One of the largest modification indices resulting from the intermediate path model suggested the addition of a path from engineering skills to knowledge of global and societal issues. While increased engineering skills could help students understand *how* to address global and societal problems, it is difficult to make an argument for increasing engineering skills resulting in an increased *knowledge of* global and societal issues. As students progress through their courses, increasing their engineering skills, it is likely that they are increasingly exposed to a broader context; however, all students in this study were seniors, suggesting that they should have roughly the same levels of knowledge. Recognizing the potential interrelationship of these two outcomes, but unable at this point to support the causal connection suggested by such a path, an error covariance between the two outcomes indicates that something outside of the model may be influencing this relationship and that further investigation of this relationship is needed.

Comparing High- and Low-CI Programs

The existence of a statistically significant difference between the unconstrained (i.e., path coefficients allowed to vary) high- and low-CI group models provides some evidence that the strength of the relationships between variables in the high- and low-CI programs differ. High programs, for example, demonstrate a more positive relationship from collaborative experiences to instructor interaction, collaborative experiences to engineering skills, collaborative experiences to knowledge of global and societal issues, instructor interaction to instructor clarity, instructor interaction to co-curricular participation, instructor clarity to knowledge of global and societal issues, and from group skills to engineering skills. Net of the influence of control variables, being in a high-CI program increases the coupling within and between student experiences and student outcomes. This suggests that high-CI programs have more coherent educational programs that connect in-class curricular experiences in-class with out-of-class experiences and with desired learning outcomes. This finding may be related to the overrepresentation of bachelor and masters institutions in the low-CI group and of research institutions in the high-CI group.

While the paths between the student pre-college characteristics and the institutional variables and student experiences are reported, they are included in the model to control for confounding influences, and their magnitude and direction is not the focus of this study. Several results related to these control variables, however, are worth noting. Of the initial paths between student pre-college characteristics and student learning experiences, with only one exception, the significant paths were to collaborative learning experiences and to participation in the co-curriculum, the experiences most within students' control, and not to instructor interaction and instructor clarity, the experiences most under the control of faculty. Institutional size and wealth, both negatively impacted students' experiences more in high-CI, than in low-CI programs. As found in the cluster analysis, high-CI programs are more likely to be found in smaller institutions suggesting that within a range of small institutions, increases in size have a more detrimental effect on students' experiences than increase in size within a range of large institutions.

Overall, the findings suggest that collective faculty attention to teaching, assessment, and curriculum planning, as expressed by the continuous improvement level of their programs, strengthens the connections within and between student experiences and outcomes. The path coefficients, while significant, are small in magnitude, as are the differences in the coefficients between models. This suggests that conclusions should be drawn with care and used to stimulate further research rather than to make sweeping generalizations about the impact of continuous improvement activities on student experiences and learning.

Although high-CI programs had a more positive (or in the case of faculty interaction to group skills, less negative) effect on the majority of the relationships between/among student experiences and student learning, in four paths, the low-CI program demonstrated a more positive effect. The mixed nature of these results suggests that the continuous improvement picture may not be a simple one. The influence of instructor clarity and of participation in the co-curriculum on engineering skills is more positive in low-CI programs, suggesting that in programs where a systematic, ongoing effort to improve teaching and curricula is not pervasive, students are more reliant on instructor clarity and on educational experiences outside of the formal curriculum to develop their engineering skills. This may be a related to larger class sizes and heavier reliance on lecture often found in research institutions.

Implications

Implications for Practice

The validation of the continuous curriculum planning variable lends support to it is utility to explore curriculum planning in higher education for increased understanding of how continuous improvement affects students' experiences and student outcomes in college. As Briggs and her colleagues (Briggs et al., 2003) suggest, these criteria may be useful to departments for self-study and curriculum improvement purposes. Further, the validation of additional variables thought to measure the continuous improvement commitment of academic departments – instructional development, undergraduate education projects, and participation in assessment – provides a broader basis upon which to evaluate departments. These criteria are particularly relevant for professional disciplines such as business, nursing, and engineering, where continuous improvement efforts are a requirement for accreditation (ABET, 2005; American Association of Colleges of Nursing, 2005; Association to Advance Collegiate Schools of Business International, 2006; National League for Nursing Accreditation Commission, 2006). While professional disciplines in particular may use the continuous improvement criteria to demonstrate their compliance with accreditation requirements and tighten curricular coherence, all academic programs may benefit from building departmental continuous improvement processes based on these criteria.

As the first study to link continuous improvement to student experiences and outcomes, this study has broad implications for institutions and programs seeking to facilitate and document improvement. The findings demonstrate that continuous improvement can have a positive influence on academic outcomes via its influence on curricular linkages. By following a continuous improvement strategy, faculty may be more intentional in creating linkages between the curriculum and the co-curriculum, stimulating student learning in multiple contexts and helping students develop an understanding of the broader context related to their studies. This study also illustrates one method for documenting the subtle nature of such influences.

Despite growing pressure to apply continuous improvement to educational processes, faculty may be resistant to change, particularly change driven by exogenous forces such as accreditors (Carothers, 1995; Olian, 1995; Tener, 1999). While further research is necessary to confirm a positive relationship between continuous improvement practices and improved educational processes, the initial findings, while modest, are promising. Although faculty members may be resistant, a growing body of evidence of the efficacy of continuous improvement activities may speak to the faculty values described by Tener (1999), particularly the appreciation for quality educational experiences and the desire for validation of educational efforts. While faculty may grudgingly adopt continuous improvement practices under the yoke of accreditation or institution-driven initiatives, evidence verifying that such practices do indeed yield positive outcomes may help trigger a shift in faculty culture. While this study focused on a single discipline, faculty across disciplines hold many of the same values, suggesting that the results of this work may have application beyond engineering. Further research in both professional and traditional academic disciplines should be conducted to verify the applicability of these findings broadly.

Implications for Policy

As both regional and specialized accrediting bodies increasingly incorporate continuous improvement principles into their accreditation criteria, evidence related to the efficacy of such policies cannot come too soon. The revision of accreditation standards can be a long and arduous process with many stakeholders vying for attention, and accreditation reviews, whether at the regional or specialized level, are a time-consuming and expensive process for institutions (Colbeck et al., 2003; Florida State Postsecondary Education Planning Commission, 1995; Marti, 1993; Moreland & Linthicum, 1981). Further, with the American system of voluntary accreditation under increasing scrutiny at the federal level, accreditors must not only do their job well, but be able to provide ample evidence of such. Accreditation criteria must be carefully vetted for their validity and their ability to sustain and improve the quality of American higher education. The *Engineering Change* study (Lattuca et al., 2006b) demonstrated that outcomes-based accreditation had a positive impact on student learning, but it did not test the role of continuous improvement. This study built on those findings and shows that continuous improvement can strengthen curricular cohesion. While the results of this study should be interpreted cautiously and further validated through additional research, they do provide indirect evidence to demonstrate the positive influence of continuous improvement practices on student learning. In this case, continuous improvement activities were motivated, at least in part, by accreditation requirements, helping to make the case for the efficacy of evolving accreditation practices related to continuous improvement. Further, the validation of the continuous improvement criteria used to distinguish programs in the study provides a set of useful measures for the evaluation of colleges' and academic programs' application of continuous improvement principles in educational process.

The findings of this study also demonstrate the limitations that can arise when only a single analytical approach is used to explore the efficacy of a policy. If the analysis had been limited to the HLM model only, the subtle influence of continuous improvement on the undergraduate educational experience would have been overlooked. This demonstrates the needs to apply multiple analytical approaches that explore both direct and indirect effects of educational interventions, in order to develop a holistic picture of their potential value.

Implications for Future Research and Theory Building

Implications for Continuous Improvement Research

As described in the introduction, the continuous improvement literature base is extensive, but it is largely a practitioner's literature focused on applying continuous improvement rather than on exploring its influence using scholarly research methods. This study not only provides empirical evidence for the use of continuous improvement as a valid construct for describing and differentiating academic programs. It also went beyond simply testing the direct and indirect effects of a continuous improvement variable (or variables) on a particular outcome, and thus demonstrated the influence that continuous improvement can have on multiple facets of the college education process, as theorized in the conceptual framework. This analysis provides the foundation for future studies of continuous improvement within engineering education and in other disciplines. The study further grounded the conceptual models of Terenzini and Reason (2005) and Lattuca, Terenzini, and Volkwein (2006a) and provides evidence to prompt further refinements to these models through the inclusion of reciprocating relationships between and among student experiences and learning outcomes.

As indicated in the implications for practice, the findings of this study warrant further exploration and should lead to additional study in fields beyond engineering. While overall the findings suggest that high-CI programs strengthen the ties between and among student experiences and student outcomes, there were some contradictory findings. Some of the relationships, for example the influence of instructor clarity and of participation in the co-curriculum on engineering skills, suggest areas for further study. While I have posited some ideas regarding the nature of these and other unexpected findings, further research is needed to test these and alternative hypotheses. Further, while it can be argued that faculty across disciplines share many similar values, similar studies should be conducted in other professional disciplines, where continuous improvement values may most resonate, and in traditional disciplines, where continuous improvement language and practice may face the most faculty resistance. Until the influence of continuous improvement activities in other disciplines is tested, generalizations beyond engineering should be made with caution.

The findings of this study contribute one of the first empirical explorations of the influence of continuous improvement on students' academic experiences and outcomes and the results suggest a number of areas for future research. While promising in nature, the magnitude of the coefficients indicates that the influences, as felt by students, are subtle in nature and difficult to tease out. Because it is unlikely that undergraduate students will be aware of the continuous improvement activities in which their faculty are involved, future studies should, like this one, include both faculty and student data. Although the continuous improvement variables in the dataset provided a basis for this research, they were small in number and in some cases (such as participation in assessment) indirect in nature. Future research in this area should ask faculty to rate or describe their activities related to the full spectrum of continuous improvement principles. Some measures of academic continuous improvement that would contribute to our understanding of the extent to which academic programs have adopted continuous improvement principles include, 1) the level of attention given by faculty to the needs of students individually and collectively, 2) the extent of faculty members' participation in continuous improvement activities, 3) faculty recognition of and understanding of the interconnected nature of students' whole (pre-college, academic, co-curricular, post-graduation success) college experience, and 4) descriptions of the ways in which faculty use assessment to improve the curriculum.

Because of the limited nature of the continuous improvement variables in the dataset, this study approached the question of continuous improvement influence by grouping engineering programs using these variables and then exploring differences in an established model of student outcomes as applied to the two groups. This approach provides a big picture of potential influence of continuous improvement activities on the entire college student experience. Futures researcher may wish to take a more direct approach by looking for the direct effects of specific continuous improvement activities on faculty behavior, and then seek to link that behavior to student outcomes, thereby exploring continuous improvement activities as a predictor, albeit an indirect one, of student outcomes in a way that allows for conclusions regarding the magnitude of the influence on learning. For example, whether increasing the amount of time instructors spend developing their teaching skills by 20 hours per year results in a measurable increase in student learning.

The core of the continuous improvement movement is the use of data to drive improvement. The continuous curriculum planning variable reflects this aspect of continuous improvement. Future research should focus on this aspect of continuous improvement and try to determine the extent to which academic programs collect data, the nature of this data, and the extent to which it feeds back into and actually improves the educational process. Researchers should not only explore the contributions of individual faculty members, but should focus specifically on the amount of program-level outcomes assessment undertaken, regardless of the number of participants, as well as how assessment is used to stimulate curriculum planning and revision. Such studies should also explore the underlying dynamic of assessment and continuous improvement - do faculty members whole-hearted buy in to evidence-based decision-making? This level of detail would have important implications both for the practice of education and for the accreditors and other stakeholders looking for approaches to improve the quality of undergraduate education.

Implications for the Conceptual Model

While this study explores continuous improvement, it is only one of many manifestations of organizational culture which may influence students' college experiences. As hypothesized in the frameworks of Lattuca, Terenzini, and Volkwein (2006) and Terenzini and Reason (2005) organizational contexts may influence student outcomes indirectly via their influence on student experiences. This study demonstrates the influence of one aspect of this context, continuous improvement, on relationship between student experiences and outcomes and opens the door to further research testing the influences of other organizational policies, practices, and cultures on college students.

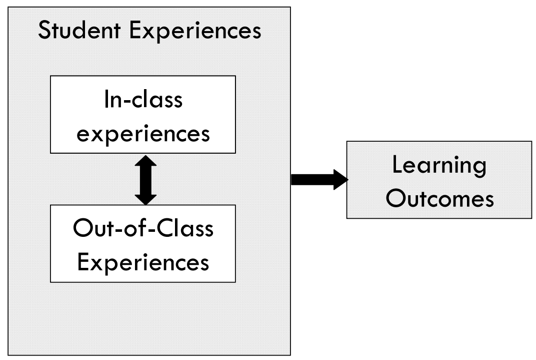
A number of relationships suggested in the final path model indicate areas for future research. Because the final model took a model-testing approach rather than a model-development approach, the results deserve further exploration. In particular, the negative path from interaction to group skills is troublesome. Further research to explain this finding is called for. While suggested that this relationship may result because instructor interaction and feedback focuses on individual achievement or because instructors who spend a great deal of time interacting and providing feedback assign less collaborative work, these hypotheses are conjecture and other explanations may be explored if the relationship holds.

The addition of paths within the student experience block of variables, within the outcomes block of variables, and from outcomes to experiences deserves further attention. While these additions to the model make sense conceptually, they represent a significant departure from prior models and should be considered independently and in relation to the model.

In past decades, higher education research has developed a number of complex models of college effects on students, for example the Lattuca et al. (2006a) model that provides the foundation for this research, as well as others such as Tinto's model of college student departure (Tinto, 1993). Because of the complexity of these models, they have been largely tested piece by piece, with studies focusing primarily on relationship between small blocks of variables. This approach was necessitated as theories outpaced analytical methods. Increasingly, statistical methods such as multilevel modeling, structural equation modeling, and time-series analyses are bringing the testing of such complex models within reach. While these methods still suffer from many practical limitations, they improve every year. The path model presented herein lays a foundation for the next era of model testing.

Although this project highlighted the difference between high- and low-CI programs and their effects on students, its most interesting and valuable contribution to our understanding of student learning in college may be the proposition that the conceptual framework is even more complex than initially conceived. The inability of the final model to clearly delineate student experiences and outcomes suggests that the common terminology used in studies of college impacts is potentially misleading because it does not capture what we know about learning. Although we accept that knowledge, values, and abilities are continually developing during college and indeed throughout life, we use the term “outcome” to describe this process. The word “outcome” suggests learning is a discrete product with clearly identifiable boundaries and a specific endpoint. The model presented in Figure 5.2 reflects an understanding of learning as an ongoing, iterative, and nonrecursive process in which student experiences in and outside the classroom influence what is learned, and what is learned influences those experiences. Furthermore, the model acknowledges that in-class and out-of-class experiences are linked in this ongoing and nonrecursive learning process.

Initial Model



Emerging Model

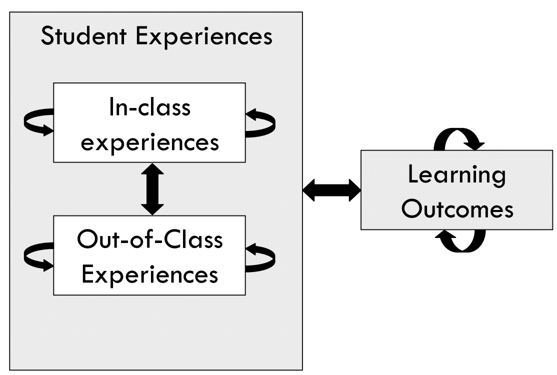


Figure 5.2: Evolution of the Conceptual Model of the Relationship between Student Experiences and Learning Outcomes

A model like the one depicted in Figure 5.2 may be tested through the use of time-series analyses that allow researchers to investigate the iterative nature of the learning process. As the use and influence of outcomes-based assessment continues to expand, it may be time to reconsider how we conceptualize learning in these studies. The approach thus far has been to consider outcome variables in isolation. My findings indicate that student learning and the student experiences are interrelated in a far more complex way than represented in most models. If "outcomes" and experiences are mutually influential, linear models that treat key variables as separate and distinct will be insufficient to represent the true nature of the learning process. Nonrecursive models have the potential to contribute to more realistic portrayals of student learning in college.

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Appendix A

SURVEYS[19]

[19] Lattuca, Terenzini, and Volkwein (2006a), pp. 365-373 and 385-394. Copyright © 2006 The Pennsylvania State University.

Survey of Seniors in Engineering Programs

(Sponsored by ABET)

Conducted by:

The Pennsylvania State University
Center for the Study of Higher Education

Please turn page to begin survey

Using pen or pencil, please fill in the appropriate box or circle with your response.

Part I. Personal Information

1. **When you entered this institution were you:**

   ○ A first-time college student ○ A transfer student from a two-year institution
   ○ A transfer student from a four-year institution

2. **What was your age when you entered this institution:** ☐☐

3. **Are you:** ○ Male ○ Female

4. **Are you a U.S. Citizen?** ○ Yes ○ No [If "no," please go to Question 6]

5. **If "Yes," with which of the following racial/ethnic groups do you closely identify? (Select all that apply.)**

   ○ White/European American ○ American Indian/Alaskan Native
   ○ Black/African American ○ Hawaiian or Pacific Islander
   ○ Hispanic or Latino ○ Other (please specify): ____________________
   ○ Asian

6. **What is the highest level of formal schooling attained by your parents or guardian?**

	Mother	Father	Guardian
High School Diploma, GED, or less	○	○	○
Some college (incl. Associate's degree)	○	○	○
Bachelor's degree	○	○	○
Advanced degree	○	○	○

7. **Approximately what is your parents'/guardians' annual family income?**

   ○ Below $20,000 ○ $90,001-$110,000
   ○ $20,001-$30,000 ○ $110,001-$130,000
   ○ $30,001-$50,000 ○ $130,001-$150,000
   ○ $50,001-$70,000 ○ More than $150,000
   ○ $70,001-$90,000

8. **Did you take the SAT or ACT tests? (Please select all that apply.)**

   ○ No. I did not take either exam.
   ○ Yes, I took the SAT exams, and my scores were approximately:
   SAT-Verbal ☐☐☐ SAT-Math ☐☐☐
   ○ Yes, I took the ACT exam, and my Composite Score was approximately: ☐☐

9. **Knowing what you know now, how well prepared were you for basic science and math courses when you entered college?**

   ○ Not at all
   ○ Slightly
   ○ Moderately
   ○ Very well prepared

10. What was your approximate overall academic average in:

	High School	College
3.50-4.00 (A- to A)	O	O
3.00-3.49 (B to A-)	O	O
2.50-2.99 (B- to B)	O	O
2.00-2.49 (C to B-)	O	O
1.50-1.99 (C- to C)	O	O
Below 1.49 (Below C-)	O	O

11. As an undergraduate, were you (select all that apply):

a. Enrolled primarily as a O Full-time student O Part-time student

b. Employed primarily
O Not employed while taking classes
O On-campus, part-time while taking classes
O Off-campus, part-time while taking classes
O Full-time while taking classes

12. As an undergraduate, approximately how many months did you spend:

	None	1 - 4	5 - 8	9 - 12	More than 12 Months
As an intern or a co-op student in industry or an engineering firm	O	O	O	O	O
In a study abroad program	O	O	O	O	O
Traveling internationally (not study abroad)	O	O	O	O	O
Involved in student design project(s)/competition(s) beyond class requirements	O	O	O	O	O

13. As an undergraduate, how active have you been in a student chapter of a professional society or engineering organization?

O Not at all O Somewhat O Moderately O Highly

Part II. Your Undergraduate Engineering Experiences

14. Thinking about your in-class and out-of-class experiences, please rate your ability to do the following:

A. Technical Skills and Abilities:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Apply knowledge of math	O	O	O	O	O
Apply knowledge of physical sciences	O	O	O	O	O
Apply discipline-specific engineering knowledge	O	O	O	O	O
Design an experiment	O	O	O	O	O
Carry out an experiment	O	O	O	O	O
Analyze evidence or data from an experiment	O	O	O	O	O
Interpret results of an experiment	O	O	O	O	O
Understand essential aspects of the engineering design process	O	O	O	O	O
Apply systematic design procedures to open-ended problems	O	O	O	O	O
Design solutions to meet desired needs	O	O	O	O	O
Define key engineering problems	O	O	O	O	O
Formulate a range of solutions to an engineering problem	O	O	O	O	O

B. Professional Skills:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Work in teams of people with a variety of skills and backgrounds	○	○	○	○	○
Work with others to accomplish team goals	○	○	○	○	○
Work in teams where knowledge and ideas from multiple engineering disciplines must be applied	○	○	○	○	○
Work through ethical issues in engineering	○	○	○	○	○
Consider ethical issues when working on engineering problems	○	○	○	○	○
Conduct yourself professionally	○	○	○	○	○
Understand the engineering code of ethics	○	○	○	○	○
Understand technical codes and standards	○	○	○	○	○
Convey ideas in writing	○	○	○	○	○
Convey ideas verbally	○	○	○	○	○
Convey ideas in formal presentations	○	○	○	○	○
Convey ideas in graphs, figures, etc.	○	○	○	○	○
Understand the impact of engineering solutions in a **global context**	○	○	○	○	○
Understand the impact of engineering solutions in a **societal context**	○	○	○	○	○
Understand contemporary issues (economic, environmental, political, societal, etc.) at the local, national, and world level	○	○	○	○	○
Understand that engineering decisions and contemporary issues can impact each other	○	○	○	○	○
Use knowledge of contemporary issues to make engineering decisions	○	○	○	○	○
Apply engineering **techniques** in engineering practice	○	○	○	○	○
Apply engineering **skills** in engineering practice	○	○	○	○	○
Apply engineering **tools** in engineering practice	○	○	○	○	○
Integrate engineering techniques, skills, and tools to solve real-world problems	○	○	○	○	○
Manage a project	○	○	○	○	○
Apply interpersonal skills in managing people	○	○	○	○	○

C. Analytical/Thinking Skills:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Break down complex problems to simpler ones	○	○	○	○	○
Apply fundamentals to problems that I haven't seen before	○	○	○	○	○
Identify critical variables, information, and/or relationships involved in a problem	○	○	○	○	○
Know when to use a formula, algorithm, or other rule	○	○	○	○	○
Recognize and understand organizing principles (laws, methods, rules, etc.) that underlie problems	○	○	○	○	○
Draw conclusions from evidence or premises	○	○	○	○	○
Develop a course of action based on my understanding of a whole system	○	○	○	○	○
Ensure that a process or product meets a variety of technical and practical criteria	○	○	○	○	○
Compare and judge alternative outcomes	○	○	○	○	○
Develop learning strategies that I can apply in my professional life	○	○	○	○	○

15. To what extent are you:	Not at All	Somewhat	Moderately	Highly
Motivated to acquire and apply new technologies and tools	○	○	○	○
Able to learn and apply new technologies and tools	○	○	○	○
Willing to take advantage of new opportunities to learn	○	○	○	○

16. How often did the following occur in the <u>courses you took in your department</u>?

	Almost Never	Occasionally	Often	Almost Always
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.	○	○	○	○
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.	○	○	○	○
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.).	○	○	○	○

17. How often did the following occur in your engineering major?

	Almost Never	Occasionally	Often	Almost Always
My engineering courses emphasized tolerance and respect for differences.	O	O	O	O
My engineering courses encouraged me to examine my beliefs and values.	O	O	O	O
My engineering friends and I discussed diversity issues.	O	O	O	O
In my major, I observed the use of offensive words, behaviors, or gestures directed at students because of their identity.	O	O	O	O
I was harassed or hassled by others in my major because of my identity.	O	O	O	O

18. Please indicate the extent to which you agree or disagree with the following statements:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The faculty in my department are committed to treating all students fairly.	O	O	O	O	O
My department emphasizes the importance of diversity in the engineering workplace.	O	O	O	O	O
I know some students who feel like they don't fit in this department because of their identity.	O	O	O	O	O
The campus climate at this institution is generally one of openness and tolerance.	O	O	O	O	O

Part III. Additional Information and Plans

19. How satisfied are you with your engineering program overall?

O Very dissatisfied O Somewhat dissatisfied O Neither satisfied nor dissatisfied O Somewhat satisfied O Very satisfied

20. What is your anticipated graduation date?

O Spring '04 O Summer '04 O Fall '04 O Other

21. What is the major field of your bachelor's degree?

O Aerospace Engineering O Electrical Engineering

O Chemical Engineering O Industrial Engineering

O Civil Engineering O Mechanical Engineering

O Computer Engineering O Other (please specify): ____________________

22. Do you have a second major or minor?

O No O Yes

O in engineering, science, or math

O outside of engineering (please specify): ____________________

23. By the end of this academic year, will you have taken the Fundamentals of Engineering (FE) Examination?

O Yes O No (please go to #24)

a. If you have taken the FE, did you pass? O Yes O No

b. How important is it to you to do well on the exam?

O Not important O Slightly important O Moderately important O Very important

24. What are your plans for the next year?

Continue undergraduate education:
- ○ Full-time
- ○ Part-time

Employment:
- ○ In an engineering-related occupation full-time
- ○ In an engineering-related occupation part-time
- ○ Outside engineering full-time
- ○ Outside engineering part-time

Graduate School:
- ○ In an engineering discipline full-time
- ○ In an engineering discipline part-time
- ○ Outside engineering full-time
- ○ Outside engineering part-time
- ○ Other (please explain): ______________________________

Thank you for your participation!

Please return your completed survey in the prepaid envelope provided.

A SURVEY OF FACULTY TEACHING AND STUDENT LEARNING IN ENGINEERING

(SPONSORED BY ABET)

Instructions: If circles are provided, please completely fill in the circle next to your answer (example: ● Yes ○ No). If boxes are provided, please write inside the box (example: [0][3]). If you are asked to specify an answer, please clearly print your answer on the line provided.

1. How many years have you been teaching as an engineering faculty member? [ ][ ] Years

2. How many years have you been a faculty member at this institution? [ ][ ] Years

3. In what engineering discipline are you employed? (If you hold a joint appointment please indicate that area as well.)

   ○ Aerospace Engineering
   ○ Chemical Engineering
   ○ Civil Engineering
   ○ Computer Engineering
   ○ Electrical Engineering
   ○ Industrial Engineering
   ○ Mechanical Engineering
   ○ Other (please specify) ______________________ ______________________

Part I Faculty Teaching

Please think about a particular undergraduate course that you teach more or less regularly. With that course in mind, please answer the following questions.

4. Please indicate the level of students in that course.

   ○ Mainly lower division
   ○ Mainly upper division
   ○ Mixed

5. Approximately how many students are enrolled in that course?

   ○ Under 20
   ○ 21-40
   ○ 41-60
   ○ More than 60

6. Indicate the category that best describes that course. (Select all that apply.)

   ○ First-year design course
   ○ Required engineering course
   ○ Capstone course
   ○ Elective/Optional engineering course
   ○ Other (specify) ________________

7. In what year did you most recently teach that course (approximately)? [ ][ ][ ][ ]

8. In what year did you first teach that course (approximately)? [ ][ ][ ][ ]

Keeping that course in mind, please answer questions 9 through 14.

9. Compared to the first time you taught that course how, if at all, has the emphasis on the following changed?

Change in emphasis on:	**Not Applicable**	**Significant Decrease**	**Some Decrease**	**No Change**	**Some Increase**	**Significant Increase**
Engineering design	○	○	○	○	○	○
Teamwork	○	○	○	○	○	○
Engineering in global/social contexts	○	○	○	○	○	○
Professional ethics	○	○	○	○	○	○
Professional responsibility	○	○	○	○	○	○
Technical writing	○	○	○	○	○	○
Verbal communication	○	○	○	○	○	○
Knowledge of contemporary issues	○	○	○	○	○	○
Experimental methods	○	○	○	○	○	○
Foundational math	○	○	○	○	○	○
Basic science	○	○	○	○	○	○
Basic engineering science	○	○	○	○	○	○
Modern engineering tools	○	○	○	○	○	○
Project management	○	○	○	○	○	○
Other (please specify)________________	○	○	○	○	○	○

10. To what extent has each of the following influenced the **course changes** above?

Extent of influence on curricular change:	**Not At All**	**Slightly**	**Moderately**	**A Great Deal**
Collective faculty decision	○	○	○	○
Change in program goals	○	○	○	○
Organizational restructuring	○	○	○	○
ABET accreditation	○	○	○	○
Student feedback	○	○	○	○
Increased resources	○	○	○	○
Decreased resources	○	○	○	○
Industry/employer feedback	○	○	○	○
Decision by Dean or other administrator	○	○	○	○
NSF coalition	○	○	○	○
Research on undergraduate engineering education	○	○	○	○
My own initiative	○	○	○	○

11. Compared to the first time you taught that course how, if at all, has the emphasis you place on the following **teaching methods** changed?

Change in emphasis on:	Not Applicable	Significant Decrease	Some Decrease	No Change	Some Increase	Significant Increase
Use of groups in class	○	○	○	○	○	○
Design projects	○	○	○	○	○	○
Assignments or exercises focusing on application	○	○	○	○	○	○
Open-ended problems	○	○	○	○	○	○
Student presentations	○	○	○	○	○	○
Hands-on experiences	○	○	○	○	○	○
Case studies or real world examples	○	○	○	○	○	○
Lectures	○	○	○	○	○	○
Computer simulations	○	○	○	○	○	○
Problems from the textbook	○	○	○	○	○	○

12. How has each of the following influenced your use of **active teaching methods**, such as group work, projects, and student presentations?

Extent of influence on instruction:	Not At All	Slightly	Moderately	A Great Deal
Collective faculty decision	○	○	○	○
Change in program goals	○	○	○	○
Organizational restructuring	○	○	○	○
ABET accreditation	○	○	○	○
NSF coalition	○	○	○	○
Student feedback	○	○	○	○
Increased resources	○	○	○	○
Decreased resources	○	○	○	○
Industry/employer feedback	○	○	○	○
My own initiative	○	○	○	○

13. Approximately how much weight do you give to each of the following when **assigning grades** in that course?

Quizzes and exams	☐☐☐ %
Class participation and presentations	☐☐☐ %
Group work or team project(s)	☐☐☐ %
Individual paper(s) or project(s)	☐☐☐ %
Homework or lab problems	☐☐☐ %
Other (please specify)________________	☐☐☐ %
TOTAL	100%

Part II Student Learning

14. What impact did the changes you made in course content and/or teaching methods have on your students' ability to do the following?

Impact of changes on students' ability to:	Does Not Apply	High Negative Impact	Some Negative Impact	No Impact	Some Positive Impact	High Positive Impact
Apply knowledge of mathematics, science, and engineering	○	○	○	○	○	○
Design and conduct experiments, as well as to analyze and interpret data	○	○	○	○	○	○
Design a system, component, or process to meet desired needs	○	○	○	○	○	○
Function on multi-disciplinary teams	○	○	○	○	○	○
Identify, formulate, and solve engineering problems	○	○	○	○	○	○
Understand professional and ethical responsibilities	○	○	○	○	○	○
Communicate effectively	○	○	○	○	○	○
Understand the impact of engineering solutions in a global and societal context	○	○	○	○	○	○
Recognize the need for and engage in life-long learning	○	○	○	○	○	○
Knowledge of contemporary issues	○	○	○	○	○	○
Use the techniques, skills, and modern engineering tools necessary for engineering practice	○	○	○	○	○	○
Manage a project	○	○	○	○	○	○

15. Think about **graduating seniors currently in your program**. On average, please rate their ability to do the following.

Graduating seniors' ability to:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Apply knowledge of mathematics, sciences and engineering	○	○	○	○	○
Design and conduct experiments, as well as to analyze and interpret data	○	○	○	○	○
Design a system, component, or process to meet desired needs	○	○	○	○	○
Function on multi-disciplinary teams	○	○	○	○	○
Ability to identify, formulate, and solve engineering problems	○	○	○	○	○
Understand professional and ethical responsibilities	○	○	○	○	○
Communicate effectively	○	○	○	○	○
Understand the impact of engineering solutions in a global and societal context	○	○	○	○	○
Recognize the need for, and engage in, life-long learning	○	○	○	○	○
Knowledge of contemporary issues	○	○	○	○	○
Use the techniques, skills, and modern engineering tools necessary for engineering practice	○	○	○	○	○
Manage a project	○	○	○	○	○

16. Compared to graduates 7-10 years ago, have current graduating seniors' abilities increased or decreased?

Change in graduates' abilities:	Greatly Decreased	Slightly Decreased	About the Same	Slightly Increased	Greatly Increased
To use engineering, math, science, and technical skills	○	○	○	○	○
To apply problem-solving skills	○	○	○	○	○
To communicate and work in teams	○	○	○	○	○
To understand the organizational, cultural, and environmental contexts and constraints of engineering practice, design, and research	○	○	○	○	○
To continue to learn, grow, and adapt as technology and society evolve in unpredictable directions	○	○	○	○	○

17. To what extent, in your opinion, are these changes attributable to ABET's EC2000?

- O Not at all
- O Some
- O Moderately
- O A great deal

18. During the past 12 months, have you participated in the following **professional development activities?** Compared to 5 years ago, is this less, the same, or more?

	Current Participation		Participation Compared To Five Years Ago		
Participation in:	**Yes**	**No**	**Less**	**Same**	**More**
Seminars or workshops on teaching and learning	O	O	O	O	O
Seminars or workshops on assessing student learning	O	O	O	O	O
Conference or journal submission on undergraduate education	O	O	O	O	O
Using services of on-campus instructional center	O	O	O	O	O
Developing or teaching a course with someone in another engineering discipline	O	O	O	O	O
Activities to enhance content knowledge	O	O	O	O	O
Reading materials on teaching	O	O	O	O	O
A project to improve undergraduate engineering education	O	O	O	O	O
Applying for external funding for an undergraduate engineering education project	O	O	O	O	O

19. Over the past decade, how has the **emphasis your program gives to teaching** changed?

Change in emphasis on teaching in:	**Significant Decrease**	**Some Decrease**	**No Change**	**Some Increase**	**Significant Increase**
Recruiting and hiring	O	O	O	O	O
Promotion and tenure	O	O	O	O	O
Salary and merit increases	O	O	O	O	O

20. To what extent do you agree or disagree with the following statements about **current curriculum planning and revision practices** in your program?

Statements about curriculum planning and revision:	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
Faculty in my program periodically review the program mission and objectives.	○	○	○	○	○
Faculty in my program generally resist new curricular ideas or experimentation.	○	○	○	○	○
Program faculty collaborate on curriculum development and revision.	○	○	○	○	○
The program curriculum is a frequent agenda item at program meetings.	○	○	○	○	○
Curriculum revisions are typically made in response to some problem rather than through a periodic planning process.	○	○	○	○	○
Curriculum planning in my program is systematic.	○	○	○	○	○
Curriculum decisions are usually based on opinions rather than data.	○	○	○	○	○
Faculty are knowledgeable about the program's curriculum beyond their own courses.	○	○	○	○	○

21. What is your level of enthusiasm for outcomes assessment as part of a process of program improvement?
    - ○ None at all
    - ○ Some
    - ○ Moderate
    - ○ A great deal

22. What has been your level of personal effort in student outcomes assessment?
    - ○ None at all
    - ○ Some
    - ○ Moderate
    - ○ A great deal

23. In your view, is that:
    - ○ Too much
    - ○ Too little
    - ○ About right

24. How much has ABET's EC2000 increased your knowledge of the strengths and weaknesses of your program?
    - ○ Not at all
    - ○ Some
    - ○ Moderately
    - ○ A great deal

25. How familiar are you with ABET's EC2000 Accreditation Criteria dealing with student outcomes?

○ Not at all
○ Slightly familiar
○ Moderately familiar
○ Very familiar

26. Approximately how many years have you been employed full-time as an engineer in industry or private practice?

☐☐ Years

27. What is your gender?

○ Male
○ Female

28. What is your ethnic background? (Indicate all that apply.)

○ White/European American
○ Black/African American
○ Hispanic or Latino
○ Asian
○ American Indian or Alaska Native
○ Hawaiian or other Pacific Islander
○ Other (please specify) ____________________

29. What is the major field of **your bachelor's degree**?

○ Aerospace Engineering
○ Chemical Engineering
○ Civil Engineering
○ Computer Engineering
○ Electrical Engineering
○ Industrial Engineering
○ Mechanical Engineering
○ Other

30. What is the major field of **your highest degree**?

○ Aerospace Engineering
○ Chemical Engineering
○ Civil Engineering
○ Computer Engineering
○ Electrical Engineering
○ Industrial Engineering
○ Mechanical Engineering
○ Other (please specify) ____________________

Thank you for your participation! Please return your completed survey in the prepaid envelope provided.

Appendix B

VARIABLES

Table B.1: Study Variables

Control Variables

<ins>Institutional characteristics (from IPEDS)</ins>
Size: 2002 enrollment (standardized)
Wealth: Average faculty salary (standardized)

<ins>Student characteristics (self-reported)</ins>
Underrepresented minority: 1 = underrepresented racial/ethnic minority (Black/African American, Hispanic/Latino, American Indian/Alaskan Native, or Hawaiian/Pacific Islander), 0 = not an underrepresented minority (White or Asian/Asian American)
Gender: 1 = male, 0 = female
Parents' education: the combined value of mother's education and father's education, each measured on a 4-point scale ranging from school diploma/GED through advanced degree
Family income: Measured on a 9-point scale ranging from below $20,000 to more than $150,000
High school GPA: Measured on a 6-point scale ranging from below 1.49 to 3.5-4.0
SAT scores: combined raw verbal and math scores

Faculty Culture

Continuous curriculum planning (8 item scale, alpha=.82)
A continuous scale average of all the individual faculty member's scores by program. Individual faculty members' score calculated by averaging the constituent items: "Faculty in my program periodically review the program mission and objectives;" "Faculty in my program generally resist new curricular ideas or experimentation;" "Faculty in my program collaborate on curriculum development and revision;" "The program curriculum is a frequent agenda item at program meetings;" "Curriculum revisions are typically made in response to some problem rather than through a periodic planning process;" "Curriculum planning in my program is systematic;" "Curriculum decisions are usually based on opinions rather than data;" "Faculty are knowledgeable about the program's curriculum beyond their own courses" (where 5 = strongly agree, to1 = strongly disagree).
Instructional development (4 item scale, alpha=.73)
A continuous scale average of all the individual faculty member's scores by program. Individual faculty members' score calculated by averaging the constituent items that assess the faculty member's participation compared to five years ago: "Participation in seminars or workshops on assessing students learning;" "Participation in seminars or workshops on teaching and learning;" "Using services of on-campus instructional center;" "Reading materials on teaching" (where 3 = more, 2 = same, and 1 = less).
Undergraduate education projects (5 item scale, alpha=.64)
A continuous scale average of all the individual faculty member's scores by program. Individual faculty members' score calculated by averaging the constituent items that assess the faculty member's participation compared to five years ago: "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" (where 3 = more, 2 = same, and 1 = less).
Enthusiasm for outcomes assessment as part of a process of program improvement (single item)
An average of all the individual faculty member's scores in each program, measured on a 4-point scale (where 4 = a great deal, to 1 = none at all).

Table B.1 continued: Study Variables

Faculty Culture
Personal effort in student outcomes assessment (single item) An average of all the individual faculty member's scores in each program, measured on a 4-point scale (where 4 = a great deal, to 1 = none at all).
Student Experiences
Collaborative learning (7 item scale, alpha=.90) An individual student's score on a continuous scale assessing how often things happened in their classes. Calculated by averaging the 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" (where 4 = almost always, to 1 = almost never). Instructor interaction and feedback (5 item scale, alpha=.87) An individual student's score on a continuous scale assessing how often things happened in their classes. Calculated by averaging the 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.)" (where 4 = almost always, to 1 = almost never). Clarity and organization (3 items scale, alpha=.82) An individual student's score on a continuous scale assessing how often things happened in their classes. Calculated by averaging the 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" (where 4 = almost always, to 1 = almost never). Internship or coop experience (single item) The students' individual score on a 5-point scale, measuring the months as an intern or cooperative education student (where 1 = none and 5 = more than 12 months). Participation in design competition (single item) The students' individual score on a 5-point scale, measuring the months spent in student design projects beyond classroom requirements (where 1 = none and 5 = more than 12 months). Student chapter of professional society (single item) The students' individual score on a 4-point scale, measuring the level of activity in a student chapter of a professional organization (where 1 = not at all and 4 = highly). Co-curriculum experience index The sum of the standardized (z-score) variables: Internship or coop experience, participation in design competition, and student chapter of professional society
Student Learning Outcomes
Applying engineering skills (4 item scale, alpha=.94) An individual student's score on a continuous scale assessing their own ability on certain outcome measures. Calculated by averaging the constituent items: "Apply engineering tools in engineering practice;" "Apply engineering skills in engineering practice;" "Apply engineering techniques in engineering practice;" "Integrate engineering techniques, skills, and tools" (where 5 = high ability, to 1 = no ability).

Table B.1 continued: Study Variables

Student Learning Outcomes
Group skills (3 item scale, alpha=.86) An individual student's score on a continuous scale assessing their own ability on certain outcome measures. Calculated by averaging the constituent items: "Work with others to accomplish team goals;" "Work in teams of people with a variety of skills and backgrounds;" "Work in teams where knowledge and ideas from multiple engineering disciplines must be applied" (where 5 = high ability, to 1 = no ability).
Societal and global issues (5 item scale, alpha=.92) An individual student's score on a continuous scale assessing their own ability on certain outcome measures. Calculated by averaging the constituent items: "Understand contemporary issues (economic, environmental, political, etc.);" "Understand that engineering decisions and contemporary issues;" "Understand the impact of engineering solutions in a societal context;" "Use knowledge of contemporary issues to make engineering decisions;" "Understand the impact of engineering solutions in a global context" (where 5 = high ability, to 1 = no ability).

Table B.2: Descriptive Statistics

	Min.	Max.	Mean	Std. Dev.	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error
Continuous improvement group	0	1	.41	.492	.363	.042	-1.869	.085
Control variables								
Student characteristics								
Gender*	.00	1.00	.794	.405	-1.453	.042	.112	.085
Minority*	0	1	.100	.294	2.752	.046	5.576	.091
Parents' education	2.00	8.00	5.178	1.863	-.251	.042	-1.007	.085
Parents' income	1.00	9.00	4.986	2.154	.196	.042	-.616	.085
High school GPA	1.00	6.00	5.645	.712	-2.469	.042	7.033	.085
SAT score	640	1638	1271	135.9	-.059	.042	.036	.085
Institution characteristics								
Size	9.01	12.39	10.711	1.080	-.029	.042	-1.469	.085
Wealth	7.57	12.60	10.196	.757	.679	.042	1.755	.085
Faculty continuous improvement variables								
Continuous curriculum planning	2.00	5.00	3.309	.511	.409	.042	-.585	.085
Instructional development	1.00	3.00	2.000	.179	.009	.042	28.202	.085
Undergraduate education projects	1.00	3.00	2.019	.169	3.581	.042	30.762	.085
Enthusiasm for assessment	1.00	4.00	2.416	.544	.398	.042	-.669	.085
Participation in assessment	2.00	4.00	2.586	.541	.125	.042	-1.049	.085
Student experiences								
Collaboration	1.00	4.00	2.930	.758	-.264	.042	-.386	.085
Feedback & interaction	1.00	4.00	2.187	.756	.332	.042	-.105	.085
Clarity	1.00	4.00	3.111	.649	-.243	.042	-.161	.085
Internship/coop	1.00	5.00	2.471	1.473	.488	.042	-1.203	.085
Design competitions	1.00	5.00	1.693	1.113	1.748	.042	2.213	.085
Professional society	1.00	4.00	2.042	1.022	.692	.042	-.648	.085
Co-curriculum	27.36	36.60	30.00	2.00	.695	.042	.088	.085
Student outcomes								
Engineering skills	1.00	5.00	4.000	.782	-.479	.042	.021	.085
Group skills	1.00	5.00	4.237	.756	-.686	.042	-.022	.085
Societal & global issues	1.00	5.00	3.686	.840	-.293	.042	-.121	.085

* Note: Weighted n=3,333 for all variables, except gender and minority which were not imputed. Gender n = 3,321, Minority n=2,891.

Appendix C

POST-HOC COMPARISONS FOR CLUSTER SOLUTIONS

Table C.1: Tukey Post-hoc Comparisons for the Four-Cluster Solution

Dependent Variable	Cluster		Mean Difference	Std. Error	P-value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Continuous Curriculum Planning	1	2	.1262	.07082	.286	-.0580	.3104
		3	.1995	.07371	.038	.0078	.3912
		4	-.8466	.11282	.000	-1.1400	-.5532
	2	1	-.1262	.07082	.286	-.3104	.0580
		3	.0733	.07918	.791	-.1326	.2792
		4	-.9728	.11647	.000	-1.2757	-.6699
	3	1	-.1995	.07371	.038	-.3912	-.0078
		2	-.0733	.07918	.791	-.2792	.1326
		4	-1.0461	.11825	.000	-1.3536	-.7386
	4	1	.8466	.11282	.000	.5532	1.1400
		2	.9728	.11647	.000	.6699	1.2757
		3	1.0461	.11825	.000	.7386	1.3536
Instructional Development	1	2	.1112	.02824	.001	.0377	.1846
		3	.3101	.02939	.000	.2337	.3865
		4	-.2511	.04499	.000	-.3681	-.1341
	2	1	-.1112	.02824	.001	-.1846	-.0377
		3	.1989	.03157	.000	.1168	.2810
		4	-.3622	.04644	.000	-.4830	-.2415
	3	1	-.3101	.02939	.000	-.3865	-.2337
		2	-.1989	.03157	.000	-.2810	-.1168
		4	-.5612	.04715	.000	-.6838	-.4385
	4	1	.2511	.04499	.000	.1341	.3681
		2	.3622	.04644	.000	.2415	.4830
		3	.5612	.04715	.000	.4385	.6838
Projects to Improve Undergraduate Education	1	2	.0554	.03510	.394	-.0359	.1467
		3	.2478	.03653	.000	.1528	.3428
		4	-.1407	.05591	.062	-.2862	.0047
	2	1	-.0554	.03510	.394	-.1467	.0359
		3	.1923	.03924	.000	.0903	.2944
		4	-.1962	.05772	.005	-.3463	-.0461
	3	1	-.2478	.03653	.000	-.3428	-.1528
		2	-.1923	.03924	.000	-.2944	-.0903
		4	-.3885	.05860	.000	-.5409	-.2361
	4	1	.1407	.05591	.062	-.0047	.2862
		2	.1962	.05772	.005	.0461	.3463
		3	.3885	.05860	.000	.2361	.5409

Table C.1 continued: Tukey Post-hoc Comparisons for the Four-Cluster Solution

Participation in Outcomes Assessment	1	2	.7432	.06302	.000	.5793	.9071
		3	.2783	.06560	.000	.1077	.4489
		4	-.4869	.10040	.000	-.7480	-.2258
	2	1	-.7432	.06302	.000	-.9071	-.5793
		3	-.4649	.07046	.000	-.6481	-.2816
		4	-1.2301	.10365	.000	-1.4996	-.9605
	3	1	-.2783	.06560	.000	-.4489	-.1077
		2	.4649	.07046	.000	.2816	.6481
		4	-.7652	.10523	.000	-1.0389	-.4915
	4	1	.4869	.10040	.000	.2258	.7480
		2	1.2301	.10365	.000	.9605	1.4996
		3	.7652	.10523	.000	.4915	1.0389

Table C.2: Fisher Least Significant Difference Post-hoc Comparisons for the Three-Cluster Solution

						95% Confidence Interval	
Dependent Variable	Cluster		Mean Difference	Std. Error	P-value	Lower Bound	Upper Bound
Continuous Curriculum Planning	1	2	0.1604	0.06038	0.009	0.0410	0.2798
		3	-0.8466	0.11276	0.000	-1.0696	-0.6237
	2	1	-0.1604	0.06038	0.009	-0.2798	-0.0410
		3	-1.0070	0.11039	0.000	-1.2253	-0.7888
	3	1	0.8466	0.11276	0.000	0.6237	1.0696
		2	1.0070	0.11039	0.000	0.7888	1.2253
Instructional Development	1	2	0.2040	0.02724	0.000	0.1501	0.2579
		3	-0.2511	0.05087	0.000	-0.3516	-0.1505
	2	1	-0.2040	0.02724	0.000	-0.2579	-0.1501
		3	-0.4551	0.04980	0.000	-0.5535	-0.3566
	3	1	0.2511	0.05087	0.000	0.1505	0.3516
		2	0.4551	0.04980	0.000	0.3566	0.5535
Projects to Improve Undergraduate Education	1	2	0.1452	0.03233	0.000	0.0813	0.2091
		3	-0.1407	0.06037	0.021	-0.2601	-0.0214
	2	1	-0.1452	0.03233	0.000	-0.2091	-0.0813
		3	-0.2859	0.05910	0.000	-0.4028	-0.1691
	3	1	0.1407	0.06037	0.021	0.0214	0.2601
		2	0.2859	0.05910	0.000	0.1691	0.4028
Participation in Outcomes Assessment	1	2	0.5262	0.06144	0.000	0.4047	0.6477
		3	-0.4869	0.11474	0.000	-0.7137	-0.2600
	2	1	-0.5262	0.06144	0.000	-0.6477	-0.4047
		3	-1.0131	0.11233	0.000	-1.2352	-0.7910
	3	1	0.4869	0.11474	0.000	0.2600	0.7137
		2	1.0131	0.11233	0.000	0.7910	1.2352

Appendix D

HLM FIXED EFFECTS

Table D.1: T-ratio and P-values for the HLM Models with Engineering Skills as the Outcome

Fixed effects	Outcome = Engineering Skills			
	Model 1 (df=141)	Model 2 (df=141)	Model 3 (df=139)	Model 4 (df=138)
Model for program means				
Average program mean	223.10***	134.13***	7.88***	7.64***
Gender		6.26***		
Parents' income		5.22***		
SAT		2.98**		
GPA		-1.49		
Minority status		-1.10		
Institution size			1.99*	1.99*
Institution wealth			-.73	-.66
CI-group				.35
Model for gender slopes				
Intercept			.67	.80
Institution size			-2.12*	-2.17*
Institution wealth			1.21	1.11
CI-group				-.60
Model for parents' income slopes				
Intercept			-.54	-.53
Institution size			-.01	-.05
Institution wealth			.97	.98
CI-group				.05
Model for SAT slopes				
Intercept			.73	.46
Institution size			-.12	-.01
Institution wealth			-.52	-.38
CI-group				1.02
Model for GPA slopes				
Intercept			.54	.24
Institution size			.68	.85
Institution wealth			-.95	-.81
CI-group				1.70
Model for minority slopes				
Intercept			1.02	1.00
Institution size			-.31	-.29
Institution wealth			-1.12	-1.11
CI-group				.10

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Table D.2: T-ratio and P-values for the HLM Models with Group Skills as the Outcome

Fixed effects	Outcome = Group Skills Model 1 (df=141)	Model 2 (df=141)	Model 3 (df=139)	Model 4 (df=138)
Model for program means				
Average program mean	250.00***	190.37***	10.32***	9.86***
Gender		-3.66***		
Parents' income		6.15***		
SAT		-3.65***		
GPA		-4.55***		
Minority status		-.56		
Institution size			1.42	1.46
Institution wealth			1.26	1.18
CI-group				-.16
Model for gender slopes				
Intercept			-.31	-.30
Institution size			-.64	.56
Institution wealth			.53	.22
CI-group				-.66
Model for parents' income slopes				
Intercept			.47	.33
Institution size			.18	.22
Institution wealth			-.31	-.20
CI-group				.98
Model for SAT slopes				
Intercept			1.59	1.58
Institution size			-.93	-1.55
Institution wealth			-1.64	-.15
CI-group				.99
Model for GPA slopes				
Intercept			.33	.18
Institution size			.32	-.65
Institution wealth			-.69	.75
CI-group				.41
Model for minority slopes				
Intercept			1.44	1.03
Institution size			-1.46	-.57
Institution wealth			-.88	1.64
CI-group				-1.34

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Table D.3: T-ratio and P-values for the HLM Models with Knowledge of Global and Societal Issues as the Outcome

Fixed effects	Outcome = Global and Societal Issues			
	Model 1 (df=141)	**Model 2 (df=141)**	**Model 3 (df=139)**	**Model 4 (df=138)**
Model for program means				
Average program mean	208.55***	141.87***	6.29***	6.23***
Gender		2.94**		
Parents' income		4.74***		
SAT		1.16		
GPA		-1.09		
Minority status		.15		
Institution size			1.76	1.80
Institution wealth			.75	.71
CI-group				-.17
Model for gender slopes				
Intercept			.94	.82
Institution size			-1.18	-1.14
Institution wealth			-.09	-.03
CI-group				.59
Model for parents' income slopes				
Intercept			.60	.52
Institution size			-.19	-.17
Institution wealth			-.35	-.30
CI-group				.34
Model for SAT slopes				
Intercept			1.05	1.07
Institution size			-.51	-.57
Institution wealth			-.85	-.82
CI-group				-.34
Model for GPA slopes				
Intercept			-.01	-.10
Institution size			.11	.18
Institution wealth			-.10	-.06
CI-group				.60
Model for minority slopes				
Intercept			2.14*	1.98*
Institution size			-1.60	-1.53
Institution wealth			-1.68	-1.57
CI-group				.77

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Appendix E

COVARIANCE MATRICES AND STRUCTURAL EQUATIONS

Table E.1: Entire Dataset Covariance Matrix, N=2,887

	Collab	Interact	Clarity	CoCurric	EngSkill	GroupSk
Collab	.47					
Interact	.21	.46				
Clarity	.07	.19	.34			
CoCurric	.28	.26	.11	4.02		
EngSkill	.10	.14	.12	.23	.57	
GroupSk	.15	.08	.06	.18	.25	.50
Societal	.10	.13	.09	.11	.35	.27
Gender	-.04	-.01	-.01	-.07	.02	-.02
Minority	.00	.00	.00	.01	-.01	.01
ParentEd	.13	.04	.04	.31	.16	.10
Income	.16	.07	.10	.24	.18	.16
HSGPA	.07	-.04	.05	.34	.07	.12
SAT	-.09	-.06	.03	.05	.08	.00
Size	-.02	-.13	-.06	-.04	.01	.03
Wealth	-.04	-.08	-.01	-.07	-.04	.03

	Societal	Gender	Minority	ParentEd	Income	HSGPA
Societal	.60					
Gender	.01	.16				
Minority	.01	.00	.09			
ParentEd	.13	-.08	-.12	6.77		
Income	.15	.06	-.11	3.16	5.32	
HSGPA	.06	.12	-.04	.97	.52	2.91
SAT	.04	.00	-.05	.95	.64	.70
Size	.03	.00	.00	.19	.09	.19
Wealth	.03	-.01	.00	.49	.27	.29

	SAT	Size	Wealth
SAT	.99		
Size	.00	1.17	
Wealth	.31	.04	.56

Table E.2: High-CI Cases Covariance Matrix, N=1,160

	Collab	Interact	Clarity	CoCurric	EngSkill	GroupSk
Collab	.45					
Interact	.23	.51				
Clarity	.10	.21	.34			
CoCurric	.29	.31	.15	3.95		
EngSkill	.11	.17	.12	.18	.58	
GroupSk	.16	.11	.09	.18	.27	.51
Societal	.11	.15	.10	.08	.38	.30
Gender	-.03	-.01	-.02	-.10	.02	-.02
ParentEd	.10	.00	.02	.29	.06	.09
Income	.16	.08	.12	.18	.16	.17
HSGPA	.03	-.03	.02	.05	.00	.03
SAT	-.07	-.05	.03	.01	.07	-.02
Size	-.05	-.19	-.06	-.22	-.02	-.01
Wealth	-.03	-.10	.00	-.11	.00	.02

	Societal	Gender	ParentEd	Income	HSGPA	SAT
Societal	.63					
Gender	.01	.16				
ParentEd	.05	-.04	3.43			
Income	.12	-.03	1.94	4.43		
HSGPA	.00	-.03	.20	.14	.48	
SAT	.02	.02	.58	.63	.20	1.00
Size	-.02	.03	.15	.07	.07	.03
Wealth	.01	-.01	.24	.23	.06	.22

	Size	Wealth
Size	1.07	
Wealth	.12	.53

Table E.3: Low-CI Cases Covariance Matrix, N=1,727

	Collab	Interact	Clarity	CoCurric	EngSkill	GroupSk
Collab	.48					
Interact	.20	.43				
Clarity	.06	.17	.34			
CoCurric	.28	.24	.09	4.06		
EngSkill	.10	.12	.12	.26	.56	
GroupSk	.15	.07	.04	.18	.23	.49
Societal	.10	.12	.08	.13	.33	.26
Gender	-.04	-.01	-.01	-.05	.03	-.02
ParentEd	.09	.04	.02	.15	.13	.06
Income	.14	.06	.07	.21	.16	.12
HSGPA	.02	-.01	.01	.14	.04	.04
SAT	-.09	-.06	.03	.07	.09	.00
Size	.01	-.08	-.07	.06	.02	.06
Wealth	-.04	-.05	-.01	-.06	.05	.03

	Societal	Gender	ParentEd	Income	HSGPA	SAT
Societal	.57					
Gender	.00	.17				
ParentEd	.12	-.07	3.35			
Income	.15	-.07	1.93	4.41		
HSGPA	.02	-.03	.21	.16	.49	
SAT	.06	-.02	.68	.53	.23	.98
Size	.06	-.01	.11	.07	.06	-.03
Wealth	.04	-.01	.35	.25	.08	.34

	Size	Wealth
Size	1.23	
Wealth	-.03	.56

Table E.4: Initial Model Structural Equations

Collab = - 0.18*Gender - 0.0036*Minority + 0.019*ParentEd + 0.033*Income + 0.046*HSGPA -
(0.039) (0.048) (0.0062) (0.012) (0.031)
-4.56 -0.075 3.06 2.77 1.49

0.15*SAT - 0.027*Size - 0.047*Wealth, Errorvar.= 0.44, R^2 = 0.070
(0.028) (0.013) (0.019) (0.011)
-5.25 -2.12 -2.45 40.32

Interact = - 0.062*Gender - 0.040*Minority + 0.015*ParentEd + 0.017*Income + 0.0080*HSGPA -
(0.039) (0.047) (0.0063) (0.011) (0.029)
-1.59 -0.86 2.38 1.55 0.27

0.059*SAT - 0.11*Size - 0.12*Wealth, Errorvar.= 0.43, R^2 = 0.066
(0.027) (0.012) (0.019) (0.012)
-2.22 -9.57 -6.66 35.95

Clarity = - 0.048*Gender + 0.0092*Minority - 0.0043*ParentEd + 0.019*Income + 0.016*HSGPA +
(0.034) (0.039) (0.0053) (0.010) (0.026)
-1.43 0.24 -0.81 1.82 0.62

0.020*SAT - 0.055*Size - 0.034*Wealth, Errorvar.= 0.33, R^2 = 0.021
(0.024) (0.010) (0.016) (0.0084)
0.87 -5.42 -2.06 39.45

CoCurric = - 0.34*Gender + 0.23*Minority + 0.033*ParentEd + 0.028*Income + 0.12*HSGPA
(0.11) (0.14) (0.018) (0.035) (0.088)
-3.08 1.65 1.87 0.80 1.34

+ 0.0034*SAT - 0.056*Size - 0.23*Wealth, Errorvar.= 3.91, R^2 = 0.025
(0.078) (0.036) (0.055) (0.11)
0.044 -1.58 -4.11 34.83

EngSkill = 0.097*Collab + 0.14*Interact + 0.24*Clarity + 0.034*CoCurric, Errorvar.= 0.50, R^2 = 0.076
(0.021) (0.019) (0.025) (0.0071) (0.013)
4.61 7.49 9.84 4.80 38.33

GroupSk = 0.30*Collab - 0.017*Interact + 0.11*Clarity + 0.022*CoCurric, Errorvar.= 0.44, R^2 = 0.10
(0.021) (0.018) (0.023) (0.0068) (0.014)
14.47 -0.93 4.97 3.25 32.02

Societal = 0.12*Collab + 0.16*Interact + 0.14*Clarity + 0.0044*CoCurric, Errorvar.= 0.55, R^2 = 0.049
(0.022) (0.020) (0.026) (0.0074) (0.015)
5.63 8.01 5.58 0.59 37.86

Table E.5: Intermediate Model Structural Equations

Collab = - 0.21*Gender + 0.020*ParentEd + 0.032*Income - 0.11*SAT - 0.043*Wealth,
(0.030) (0.0062) (0.011) (0.015) (0.018)
-7.16 3.27 2.98 -7.68 -2.40

Errorvar.= 0.44, R^2 = 0.058
(0.010)
42.20

Interact = 0.024*ParentEd - 0.049*SAT - 0.11*Size - 0.12*Wealth, Errorvar.= 0.44, R^2 = 0.061
(0.0078) (0.015) (0.012) (0.019) (0.011)
3.10 -3.33 -9.72 -6.58 38.60

Clarity = - 0.053*Size, Errorvar.= 0.34 , R^2 = 0.0098
(0.011) (0.0097)
-5.05 34.51

CoCurric = - 0.36*Gender + 0.041*ParentEd + 0.11*HSGPA - 0.22*Wealth, Errorvar.= 3.92 , R^2 = 0.023
(0.10) (0.018) (0.076) (0.056) (0.11)
-3.55 2.34 1.48 -3.93 36.37

EngSkill = 0.097*Collab + 0.14*Interact + 0.24*Clarity + 0.034*CoCurric, Errorvar.= 0.50, R^2 = 0.074
(0.021) (0.019) (0.025) (0.0071) (0.013)
4.55 7.40 9.76 4.77 38.34

GroupSk = 0.30*Collab + 0.11*Clarity + 0.022*CoCurric, Errorvar.= 0.44, R^2 = 0.096
(0.021) (0.023) (0.0069) (0.014)
13.88 4.56 3.15 31.95

Societal = 0.13*Collab + 0.16*Interact + 0.14*Clarity, Errorvar.= 0.55, R^2 = 0.048
(0.022) (0.021) (0.026) (0.015)
5.62 7.97 5.54 37.83

Table E.6: Final Model Structural Equations

Collab = - 0.21*Gender + 0.020*ParentEd + 0.032*Income - 0.11*SAT - 0.043*Wealth,

(0.030)	(0.0062)	(0.011)	(0.015)	(0.018)
-7.16	3.27	2.98	-7.68	-2.40

Errorvar.= 0.44, R^2 = 0.058

(0.010)
42.20

Interact = 0.35*Collab + 0.28*GroupSk - 0.11*Size - 0.12*Wealth, Errorvar.= 0.37, R^2 = 0.20

(0.021)	(0.034)	(0.011)	(0.017)	(0.012)
16.67	7.99	-9.94	-7.08	29.96

Clarity = 0.39*Interact + 0.054*SAT, Errorvar.= 0.26 , R^2 = 0.23

(0.015)	(0.011)	(0.0072)
26.84	5.04	36.51

CoCurric = 0.52*Interact - 0.31*Gender + 0.033*ParentEd + 0.12*HSGPA - 0.14*Wealth,

(0.055)	(0.099)	(0.017)	(0.075)	(0.056)
9.45	-3.15	1.91	1.56	-2.59

Errorvar.= 3.80 , R^2 = 0.054

(0.11)
35.28

EngSkill = 0.16*Collab + 0.24*Clarity + 0.030*CoCurric, Errorvar.= 0.51, R^2 = 0.10

(0.022)	(0.027)	(0.0058)	(0.013)
7.57	9.11	5.25	39.39

GroupSk = 0.35*Collab - 0.34*Interact + 0.25*EngSkill + 0.32*Societal, Errorvar.= 0.35, R^2 = 0.30

(0.025)	(0.037)	(0.021)	(0.021)	(0.013)
14.09	-9.14	12.01	15.28	26.60

Societal = 0.20*Collab + 0.14*Clarity, Errorvar.= 0.56, R^2 = 0.063

(0.023)	(0.028)	(0.015)
8.71	5.13	37.98

Error Covariance for Societal and EngSkill = 0.31

(0.012)
26.50

Table E.7: Multiple Group Constrained Model Structural Equations

Collab = - 0.21*Gender + 0.028*ParentEd + 0.036*Income - 0.11*SAT - 0.042*Wealth,
(0.029) (0.0080) (0.0068) (0.014) (0.018)
-7.16 3.51 5.26 -7.86 -2.34

Errorvar.= 0.43, R^2 = 0.059
(0.016)
27.35

Interact = 0.34*Collab + 0.28*GroupSk - 0.11*Size - 0.11*Wealth, Errorvar.= 0.38, R^2 = 0.19
(0.021) (0.035) (0.011) (0.015) (0.016)
16.49 8.00 -10.08 -7.61 22.94

Clarity = 0.39*Interact + 0.053*SAT, Errorvar.= 0.25, R^2 = 0.24
(0.014) (0.0099) (0.010)
27.40 5.42 24.21

CoCurric = 0.53*Interact - 0.35*Gender + 0.051*ParentEd + 0.21*HSGPA - 0.14*Wealth,
(0.055) (0.086) (0.021) (0.057) (0.052)
9.71 -4.09 2.47 3.60 -2.63

Errorvar.= 3.69 , R^2 = 0.055
(0.15)
23.83

EngSkill = 0.16*Collab + 0.24*Clarity + 0.030*CoCurric, Errorvar.= 0.50, R^2 = 0.10
(0.021) (0.026) (0.0055) (0.018)
8.02 9.35 5.35 27.71

GroupSk = 0.35*Collab - 0.34*Interact + 0.25*EngSkill + 0.32*Societal, Errorvar.= 0.35, R^2 = 0.29
(0.023) (0.037) (0.021) (0.020) (0.017)
15.37 -9.29 12.06 15.70 20.62

Societal = 0.20*Collab + 0.14*Clarity, Errorvar.= 0.57, R^2 = 0.060
(0.022) (0.027) (0.020)
9.11 5.24 28.11

Error Covariance for Societal and EngSkill = 0.31
(0.011)
26.91

Table E.8: Multiple Group Base Model Structural Equations

Collab = - 0.16*Gender + 0.022*ParentEd + 0.042*Income - 0.092*SAT - 0.053*Wealth,
(0.047) (0.012) (0.011) (0.021) (0.027)
-3.47 1.74 3.89 -4.43 -1.94

Errorvar.= 0.42, R^2 = 0.049
(0.016)
27.40

Interact = 0.39*Collab + 0.26*GroupSk - 0.14*Size - 0.14*Wealth, Errorvar.= 0.37, R^2 = 0.26
(0.034) (0.051) (0.018) (0.024) (0.017)
11.43 5.04 -8.08 -5.93 21.51

Clarity = 0.41*Interact + 0.052*SAT, Errorvar.= 0.25, R^2 = 0.27
(0.021) (0.015) (0.010)
20.05 3.50 24.17

CoCurric = 0.55*Interact - 0.55*Gender + 0.085*ParentEd + 0.077*HSGPA - 0.16*Wealth,
(0.081) (0.14) (0.031) (0.089) (0.079)
6.89 -3.85 2.73 0.87 -1.99

Errorvar.= 3.68 , R^2 = 0.069
(0.15)
23.84

EngSkill = 0.18*Collab + 0.22*Clarity + 0.022*CoCurric, Errorvar.= 0.52, R^2 = 0.094
(0.032) (0.040) (0.0087) (0.021)
5.63 5.43 2.49 24.84

GroupSk = 0.35*Collab - 0.29*Interact + 0.28*EngSkill + 0.30*Societal, Errorvar.= 0.34, R^2 = 0.33
(0.038) (0.052) (0.032) (0.031) (0.018)
9.39 -5.54 8.91 9.60 19.44

Societal = 0.22*Collab + 0.15*Clarity, Errorvar.= 0.59, R^2 = 0.069
(0.035) (0.043) (0.024)
6.23 3.57 24.31

Error Covariance for Societal and EngSkill = 0.33
(0.019)
17.46

Appendix F

REGRESSION ANALYSES

Table F.1: Standardized Betas with Engineering Skills as the Outcome Variable

	Model 1		Model 2		Model 3	
	Low-CI	**High-CI**	**Low-CI**	**High-CI**	**Low-CI**	**High-CI**
Gender	.109 (.000)	.074 (.007)	.127 (.000)	.096 (.000)	.129 (.000)	.096 (.000)
Black						
Hispanic						
Asian						
American Indian						
Hawaiian						
Other						
Parents' education						
Family income	.080 (.002)	.108 (.001)	.046 (.053)	.070 (.017)	.047 (.049)	.065 (.026)
SAT Total		.078 (.013)	.070 (.009)	.096 (.001)	.079 (.004)	.102 (.001)
High school GPA	.059 (.013)					
Z-size			.058 (.007)		.062 (.006)	
Z-wealth						
Intern/coop			.067 (.002)	.054 (.035)	.065 (.003)	
Design competitions			.101 (.000)	.081 (.002)	.102 (.000)	.081 (.002)
Professional society						
Clarity			.206 (.000)	.156 (.000)	.204 (.000)	.154 (.000)
Collaboration			.139 (.000)	.098 (.001)	.144 (.000)	.108 (.000)
Interaction			.100 (.000)	.203 (.000)	.099 (.000)	.202 (.000)
Continuous curriculum planning						
Enthusiasm for assessment						
Participation in assessment						-.102 (.002)
Instructional development						
Projects to improve undergraduate education						

Note: P-values reported in parenthesis.

Table F.2: Standardized Betas with Group Skills as the Outcome Variable

	Model 1		Model 2		Model 3	
	Low-CI	High-CI	Low-CI	High-CI	Low-CI	High-CI
Gender						
Black	.069 (.002)		.068 (.002)		.072 (.001)	
Hispanic						
Asian		-.105 (.000)		-.070 (.007)		-.070 (.008)
American Indian						
Hawaiian						
Other		-.080 (.003)		-.057 (.024)		-.058 (.022)
Parents' education						
Family income	.105 (.000)	.131 (.000)	.070 (.004)	.088 (.003)	.072 (.003)	.088 (.003)
SAT Total	-.078 (.006)	-.082 (.008)				
High school GPA	.095 (.000)	.062 (.030)	.065 (.004)		.070 (.002)	
Z-size	.045 (.044)		.052 (.017)		.054 (.018)	
Z-wealth		.086 (.002)	.051 (.040)	.094 (.001)	.053 (.044)	.104 (.000)
Intern/coop			.047 (.030)		.047 (.030)	
Design competitions				.052 (.047)		.054 (.042)
Professional society						
Clarity			.072 (.002)	.116 (.000)	.069 (.004)	.115 (.000)
Collaboration			.297 (.000)	.280 (.000)	.303 (.000)	.277 (.000)
Interaction						
Continuous curriculum planning						
Enthusiasm for assessment						
Participation in assessment						
Instructional development					.060 (.028)	
Projects to improve undergraduate education						

Note: P-values reported in parenthesis.

Table F.3: Standardized Betas with Knowledge of Societal and Global Issues as the Outcome Variable

	Model 1		Model 2		Model 3	
	Low-CI	**High-CI**	**Low-CI**	**High-CI**	**Low-CI**	**High-CI**
Gender		.054 (.050)	.056 (.010)	.067 (.012)	.059 (.008)	.069 (.010)
Black						
Hispanic				.053 (.044)		.056 (.035)
Asian						
American Indian		.054 (.051)	.043 (.051)	.056 (.033)	.043 (.050)	.059 (.024)
Hawaiian						
Other						
Parents' education						
Family income	.077 (.003)	.095 (.002)	.053 (.031)	.063 (.036)	.055 (.027)	.062 (.040)
SAT Total			.054 (.051)		.068 (.016)	
High school GPA						
Z-size	.051 (.024)		.081 (.000)		.084 (.000)	
Z-wealth					.062 (.019)	
Intern/coop						
Design competitions						
Professional society						
Clarity			.104 (.000)	.121 (.000)	.100 (.000)	.124 (.000)
Collaboration			.125 (.000)	.125 (.000)	.126 (.000)	.131 (.000)
Interaction			.156 (.000)	.170 (.000)	.157 (.000)	.171 (.000)
Continuous curriculum planning					-.062 (.009)	
Enthusiasm for assessment						
Participation in assessment						
Instructional development						
Projects to improve undergraduate education						.056 (.041)

Note: P-values reported in parenthesis.

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Education

Doctor of Philosophy in Higher Education, minor in Educational Psychology, and graduate certificate in Institutional Research - *The Pennsylvania State University*, 2008
Master of Science in Wildlife Ecology with a Minor in Statistics - *University of Florida*, 1999
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Professional Experience

Graduate Research Assistant, Penn State Higher Education Program, 2004–08
Research Associate, Rankin and Associates Consulting, 2004-current
Undergraduate Program Coordinator, Penn State School of Forest Resources, 1999-04
Graduate Research Assistant, University of Florida Department of Wildlife Ecology, 1997-99
Biological Consultant, The Nature Conservancy, 1998-99

Selected Publications

Volkwein, J. F., Lattuca, L. R., **Harper, B. J**., & Domingo, R. J. (2007). Measuring the impact of professional accreditation on student experiences and learning outcomes. *Research in Higher Education, 48*(2), 251-282.

Lattuca, L. R., Terenzini, P. T., & Volkwein (with J. F., Strauss, L. C., Baker, V. L., Domingo, R. J., **Harper B. J.,** & Sukhbaatar, J.) (2006). *Engineering change: A study of the impact of EC2000. Final Report*. Baltimore, MD: ABET.

Harper, B. J. (2006). Women's colleges in the era of gender equity: A review of the literature on the effects of institutional gender on women. *Higher Education in Review, 3,* 1-24.

Presentations

Terenzini, P. T. & **Harper, B. J.** (2008, June 22-25*). The effects of instructors' time in industry on students' co-curricular experiences*. Paper presented at the annual meeting of the American Society for Engineering Education, Pittsburgh, PA.

Harper, B. J. & Terenzini, P. T. (2008, May 24-28). *Lost in translation: The effects of instructors' time in industry on students' engineering experiences*. Paper presented at the annual meeting of the Association for Institutional Research, Seattle, WA.

Harper, B. J. (2008, March 24-28). *Continuous improvement attitudes and behaviors: Assessing faculty practices in academic programs.* Paper presented at the annual meeting of the American Educational Research Association, New York, NY.

Harper, B. J., Lambert, A. D., & Lattuca, L. R. (2006, Nov. 2-4). *The interaction of student race and experiences: Critical influences on learning outcomes in engineering*. Paper presented at the annual meeting of the Association for the Study of Higher Education, Anaheim, CA.

Teaching

Instructor, *First-Year Seminar*, Fall 2002 and 2003
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Editor, *Higher Education in Review*, 2007–08; Assistant Editor, 2006-07; Web Editor, 2005-07
Appointed member: Penn State Commission for LGBT Equity, 2005-2008
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