CONSTRUCTING THE CONCEPT OF CONTEXTUAL COMPETENCE IN AN UNDERGRADUATE ENGINEERING CURRICULUM

by

CAROL CARMICHAEL

(Under the Direction of Libby V. Morris)

ABSTRACT

A two-questionnaire protocol for exploring how faculty members in an academic program perceive a multidisciplinary outcome was developed and demonstrated in an undergraduate engineering program. The case study provides a detailed description of how faculty members in an undergraduate chemical engineering program at a doctoral-level university perceive contextual competence, a multidisciplinary outcome of engineering education that lies in the common ground between general education and the major. The study included faculty from chemical engineering and the humanities and social sciences responsible for teaching the general education component of the curriculum. What distinguishes this study from previous work is the holistic exploration of these issues within a specific academic program rather than the multi-institution contexts of previous studies. The protocol results provide guidance to the faculty in the chemical engineering program on how to approach the enduring challenge of integrating learning across the two stems of the engineering curriculum. It addresses the fundamental challenges to curriculum coherence: the development of shared goals and objectives among faculty members responsible for general education and the major, and the selection of relevant courses and evaluation methods to achieve them. The case study provided four types of information that can be used to begin a constructive dialogue process on shared objectives between faculty in engineering and the humanities and social sciences. (1) The results showed that the chemical engineering faculty viewed the two-questionnaire protocol as an authentic process for program improvement by the chemical engineering faculty. (2) The protocol yielded an operational definition of contextual competence characterized by 70 outcome attributes in seven thematic areas. (3) Data obtained from the protocol was used to identify areas of consensus among the faculty on the outcome definition, courses in the curriculum relevant to developing contextual competence, and appropriate evaluation methods. (4) The protocol provided insight into the social connectedness among the faculty participants and the opportunities for implementing a dialogue process on shared educational objectives.

INDEX WORDS: engineering education, faculty objectives, contextual competence, multidisciplinary outcomes, academic program planning, general education

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CHAPTER 1

INTRODUCTION

Statement of the Problem

In his study of engineering design, Bucciarelli uncovers the social process of design by describing how the members of a design team, holding different perceptions of a problem, arrive at a consensus for the design through a process of dialogue and negotiation (Bucciarelli, 1994). The imperative to deliver a finished design creates a social and cognitive space into which the team members juxtapose their different values, objectives, and perceptions of the problem. The juxtaposition of perspectives stimulates learning among the team members and eventually leads to the final, negotiated design concept. Bucciarelli's study shows that engineering design is fundamentally a social process that incorporates knowledge from science and engineering, insight from experience, and understanding of the relationship between technical design and the broader societal context.

In the same sense, the design of an academic program for educating engineers is a social process, described by Stark and Lattuca (1997) as the academic planning process. In Stark and Lattuca's concept of an academic plan, the design team members are the external, organizational, and internal stakeholders in the academic program. The educational environment created by an academic department serves as the mediating space in which the demands of the stakeholders are negotiated and transformed into the substance of an academic program. It is in this space where the faculty members design an academic curriculum, defining its purpose, goals and objectives, selecting content and arranging it into a sequence of courses, and identifying the appropriate instructional and evaluation processes to be used. In the end, the curriculum as designed and implemented by the faculty is a social construct involving multiple perspectives that coalesce around a consensus on the desired outcomes of the educational process (Guba & Lincoln, 1994; Schwandt, 1994).

Contextual Competence and the Academic Program

The objectives of engineering education in the U.S. support the idea of engineering design as a social construction process. One objective in particular, the development of contextual competence, addresses the types of social and technical understanding needed by the members of the design team in Bucciarelli's study. Contextual competence is defined by the Accreditation Board for Engineering and Technology (ABET) as "the broad education necessary to understand the impact of engineering solutions in a global and societal context." A broad education is necessary because contextual competence involves developing perspectives that are inherently multidisciplinary.

The development of an academic program to achieve the socio-humanistic objectives of engineering education involves more than the adoption of definitions provided by the accreditation board. When the outcomes were updated in the ABET engineering criteria for the year 2000, some researchers questioned whether the engineering community had "overlooked an important step" in the academic planning process. Besterfield-Sacre and her colleagues observed that the engineering community had failed to "comprehensively examine the meaning of these learning outcomes and hypothesize how [the] focus on each may result in an improved education environment" (Besterfield-Sacre, Shuman et al., 2000).

What had been overlooked was the constructive process of faculty members in an academic program interpreting and defining these outcomes for their own particular academic context. Besterfield-Sacre and her colleagues diagnosed the problem as a “lack of construct specificity.” They argued that

> faculty consensus is required if successful implementation is to follow. This consensus must encompass definitions, performance criteria, and assessment processes (Besterfield-Sacre, Shuman et al., 2000).

Besterfield-Sacre and her colleagues found that several multidisciplinary outcomes in the engineering criteria, including contextual competence, are “particularly difficult” to define and could have multiple definitions. For the academic programs to be effective in achieving these outcomes, the engineering faculty members needed to develop operational definitions for these outcomes appropriate for their particular institutional context and explore opportunities for integration of objectives and content across courses in the curriculum (Besterfield-Sacre, Shuman et al., 2000).

One reason that contextual competence is so difficult to define and implement in an academic program is that it is multidisciplinary. It bridges the divide between engineering and the humanities and social sciences and challenges the faculty to address coherence between general education and the major. The faculty design team for the engineering program, in theory, would be expanded to include colleagues in the humanities and social sciences responsible for teaching courses in the general education component of the curriculum. The difficulty is that there is no mediating space in which the values, objectives and perceptions of the design team can be brought into relief. There is no process for dialogue and consensus among the faculty members on the definition of contextual competence, the courses in which it would be developed, or the evaluation methods to be used. The challenges to addressing such multidisciplinary outcomes in an academic program are legendary. They have been documented in decades of reports on the status of engineering education in particular, and the problem of coherence in the undergraduate curriculum in general.

The Need for Research on Multidisciplinary Outcomes in Engineering

Research on academic programs often focuses on explaining how external, organizational or internal factors influence an academic program, or how the particular design of an academic program influences student outcomes. The study designs tend to be positivist in nature, involving the development of descriptive and/or causal models or employing sampling and data collection schemes that allow for inferences to be made about a population or broader class of phenomena (Astin, 1993; Stark & Lattuca, 1997). Such studies, while informative, do not provide insight into how faculty members from several disciplines would build a consensus around a multidisciplinary outcome within an academic program.

Little is known about how the faculty in engineering and the humanities and social sciences define multidisciplinary outcomes such as contextual competence, how the curriculum is designed to help students develop such competencies, or how students would demonstrate their learning. Prior research does provide some insight into these questions. Researchers have examined the objectives shared by professional and liberal education programs, the attitudes of faculty in engineering and other disciplines toward general and liberal education outcomes, and the beliefs held by faculty regarding their roles in shaping the values and attitudes of their students. For the most part, these studies focus on faculty and educational outcomes in an abstract sense, aggregating results by professional field or discipline and analyzing the influence of various contextual factors such as institutional type, gender and age of the faculty, or academic rank and tenure status. While previous studies provide some insight into the perceptions held by the faculty regarding the more socio-humanistic (multidisciplinary) outcomes in the engineering curriculum, they do not guide faculty members interested in improving the effectiveness of their particular academic programs with respect to these outcomes.

Purpose

This study bridges the gap between the abstract knowledge gained from prior research and the concrete knowledge on faculty perceptions of contextual competence in an existing academic program. The study has two purposes: (1) to develop a protocol for exploring how faculty members in an academic program perceive a multidisciplinary outcome (its definition, its relationship to courses in the curriculum, and methods for assessing it); and (2) to demonstrate the use of the protocol in a particular academic program in engineering.

The philosophical underpinning of the study design is the social constructivist view of engineering as a discipline, the academic planning process, and the curriculum. Therefore, the study design is based on the following assumptions:

1. Knowledge about the curriculum is inextricably tied to the context of the academic program.
2. Multiple definitions of the concept of contextual competence, and perceptions about its relationship to courses in the curriculum, exist among faculty in an academic program.
3. Explicit descriptions of how faculty members in an academic program define the concept of contextual competence, and juxtaposition of these definitions in a mediated space, can influence how individual faculty members participating in the study define the concept.

Research Questions

This study addresses two types of research questions: (1) those related to the proposed case study and the concept of contextual competence; and (2) those related to the development of the protocol and its utility for improving the effectiveness of an academic program with respect to multidisciplinary outcomes. The study includes five research questions:

1. How do faculty members in engineering and in the humanities and social sciences define contextual competence?
2. In which courses in the undergraduate curriculum do faculty members in engineering and in the humanities and social sciences believe contextual competence is best developed?
3. Do faculty in engineering and in the humanities and social sciences believe that adequate emphasis is placed on contextual competence in engineering courses or in courses in the humanities and social sciences?
4. How would faculty members in engineering and in the humanities and social sciences evaluate student achievement of contextual competence? When and where (e.g., in what courses) in the academic program would they evaluate student achievement?
5. What effect does participation in the protocol have on how engineering faculty define contextual competence? Does the protocol provide useful information for faculty members interested in academic program improvement?

Plan of the Study

This study employs an embedded case study as its strategy of inquiry (Stark & Lattuca, 1997; Yin, 1994). The study design addresses the limitations of prior research on academic programs that used quantitative research designs that increased theoretical rigor but decreased the relevance of the results for program evaluation by stripping the problems of their context (Greene, 1994; Guba & Lincoln, 1994). The study site is the School of Chemical and Biomolecular Engineering at the Georgia Institute of Technology in Atlanta, Georgia, which administers the Bachelor of Science degree in chemical engineering. The case study highlights faculty members in chemical engineering and the complement of humanities and social sciences faculty responsible for teaching the general education component of the curriculum. The study site was selected because of its relatively large size, its focus on teaching and research, and its quality as ranked by peers in the academy. The goal was to select a site that would be viewed as relevant by faculty members and administrators in similar contexts who are interested in program improvement with respect to multidisciplinary outcomes such as contextual competence. A second goal was to select a site where one would likely find dissimilar, more discipline-oriented perspectives on multidisciplinary outcomes between the faculties in engineering and in the humanities and social sciences. It was determined that an academic program with general education based on distribution requirements, as opposed to a more integrated curriculum structure, would meet the site selection goals of the study.

The case study involves the development and implementation of a two-questionnaire protocol as the main method for data collection. The first questionnaire was designed to solicit input from the faculty members in engineering and the humanities and social sciences on (a) the definition of contextual competence; (b) the methods they would use to assess it; (c) their opinions on the contribution of coursework in engineering and the humanities and social sciences to the development of it; (d) their involvement in curriculum activities and discussions, and (e) the individuals they would contact for more information on contextual competence. The second questionnaire presents 70 outcome attributes of contextual competence derived from the responses from both groups of faculty to the first questionnaire. The questionnaire was administered only to the chemical engineering respondents to the first questionnaire because primary responsibility for evaluation and improvement activities related to the chemical engineering curriculum belongs to them. The goals of the second questionnaire were to identify a consensus definition of contextual competence among the chemical engineering respondents, to identify those attributes of the definition they share in common with their colleagues in the humanities and social sciences, and to assess the authenticity of the protocol for use in academic program improvement. In essence, the second questionnaire in the protocol was designed to serve as a mediating space in the curriculum where faculty in engineering and the humanities and social sciences could begin a dialogue on the goals and objectives for a multidisciplinary outcome.

Significance of the Study

The protocol developed and implemented in this study addresses the most significant challenge to improving academic programs with respect to multidisciplinary outcomes such as contextual competence. It mitigates the barriers of indifference and inter-departmental politics by placing faculty members into an indirect dialogue process on educational objectives and the curriculum. It provides detailed information on the definition of a multidisciplinary outcome and guidance to program administrators on opportunities in the curriculum for improving the effectiveness of the academic program. The results obtained from the two-questionnaire protocol create a relevant and focused foundation for continued dialogue within the faculty of chemical engineering and across the faculties in engineering and the humanities and social sciences. Finally, the results of the particular case in chemical engineering are of interest to faculty in peer institutions responsible collectively for conferring over one-quarter of the bachelor’s degrees in chemical engineering nationally each year.

The protocol results can also be used to enrich program assessment studies required for accreditation under the auspices of ABET. The protocol is intended for use in a voluntary, internal program review process that seeks to understand and document the relationship between what students have learned and the key characteristics of the academic program and the curriculum designed by the faculty (Ewell, 1997). In recent years, several researchers have developed methods for assessing student outcomes in engineering, including the assessment of contextual issues considered by students during design, and changes in student attitudes toward the global and societal issues arising from engineering problems (Atman & Bursic, 1998; Atman, Chimka, Bursic, & Nachtmann, 1999; Atman & Nair, 1996; Besterfield-Sacre, Atman, & Shuman, 1998; Besterfield-Sacre et al., 1996). The results of such assessments do not directly inform faculty and administrators on the particular curriculum characteristics relevant to the student outcomes, but they do provide indirect evidence of curricular coherence or consensus on educational goals among the faculty in engineering and the humanities and social sciences. The utility of outcome assessment methods for program improvement is limited by the lack of a method for systematically describing those characteristics of the curriculum relevant to producing the outcome of interest. By providing such information, the protocol developed in this study can be used to enrich the interpretation of assessment results related to student development of contextual competence or other multidisciplinary outcomes.

Limitations

The transferability of the study results is limited by the use of a case study design. The particular results obtained for the participating faculty members in the case study cannot be generalized to other engineering disciplines at Georgia Tech or to chemical engineering programs in other institutions. The case study protocol, however, can be used as designed to explore contextual competence in other departments of chemical engineering in any institutional context. The protocol can be adapted to study faculty perceptions in other academic programs that have multidisciplinary outcomes incorporating learning in courses taught by faculty in engineering and in the humanities and social sciences. While the use of procedural guidelines was intended to enhance the authenticity of the researcher's interpretations "as empirically based representations" of the faculty responses, the use of such guidelines in a case study format does not increase the transferability of the particular case beyond its instrumental or revelatory value to other programs and institutions (Greene, 1994, p. 537).

Definition of Terms

This study uses several terms which may have multiple definitions and meanings to the reader. The terms are defined to facilitate understanding and interpretation of the results of this study.

Competencies, Outcomes, and Attributes

A student learning outcome is an educational objective or competency (Besterfield-Sacre, Shuman et al., 2000), and a competency is a demonstration of adequate ability (Gross, 1988). The criteria for engineering education specified by the American Board for Engineering and Technology (ABET) specify 11 outcomes, including contextual competence. The engineering criteria identify the general subject areas and competencies appropriate to each engineering discipline, but they do not prescribe specific course content or instructional methods. The outcomes of engineering education can be described more specifically using a set of attributes (Besterfield-Sacre, Shulman et al., 2000; Besterfield-Sacre, Shuman et al., 2000). In this study the terms attributes and outcome attributes are used to describe distinct competencies that can be interpreted with only "a broad understanding of the context" of the educational objective (Merriam, 1988, p. 132).

Contextual Competence

This study uses the definition of contextual competence developed by Stark (1986):

> "Contextual competence" signifies an understanding of the broad social, economic, and cultural setting in which the profession is practiced (McGlothlin, 1964). It refers not only to the professional's specific work setting, but also to the larger environments, both social and natural, within which the work is embedded. The acquisition of the competence implies that the student can examine the environmental context from a variety of vantage points: historical, social, economic, psychological, political, and philosophical. The capability to adopt multiple perspectives allows the student to comprehend the complex interdependencies between the profession and society, thus fostering both increased professional awareness and more effective citizenship (cited in Stark, Lowther, Hagerty, & Orczyk, 1986, p. 235)

Protocol

A protocol is a plan for carrying out a study. In this study, the protocol refers to the faculty and site selection procedures, the two questionnaires developed for this study, and the procedures for data collection and analysis using the two questionnaires.

Liberal Education

Liberal education comprises the knowledge and skills considered essential for the learned individual and for the preservation of cultural heritage. The liberal education curriculum has its origins in the liberal arts of logic, rhetoric, ethics, mental philosophy or metaphysics, astronomy, natural philosophy or physics, and mathematics. While having practical implications for the individual and society, a liberal education is non-vocational in intent. The concept of liberal education, its philosophical orientation and curricular content, has changed over time to accommodate intellectual developments and the changing needs of society (Rudolph, 1977).

General Education

General education addresses the personal needs of the individual and the broader needs of a democratic society. It has its origins in the liberal arts and sciences, is comprehensive, and is intended to balance the perceived narrowness of specialized education in the major. The purpose, structure, and content of general education are defined by the academic institution. General education is defined by a set of educational objectives satisfied through a set of common courses (prescriptive) or through courses selected by the students according to subject area and credit distribution requirements (elective). General education involves learning inside and outside of the classroom (Gaff, Ratcliff, & Associates, 1997; Miller, 1988; Ratcliff, 1997).

General versus Liberal Education

Over the past 50 years, the concept of liberal education has been replaced in many institutions with general education (Miller, 1988). The terms liberal and general education are often used interchangeably to describe coursework taken outside the major field of study. In Chapter 2, both terms are used and their use reflects the terminology selected by the authors of the sources of literature reviewed.

Professional Education

Professional education applies to undergraduate academic programs requiring “four years or more of education to gain basic career entry in a specific occupational field” (Stark, Lowther, Hagerty et al., 1986). Engineering education is one type of professional education. The curriculum for such programs includes courses in general education and the major. In the engineering curriculum, the curriculum is divided into two stems: (1) math, science, and engineering or technical courses; and (2) humanities and social science courses (Hammond, 1940). Professional education programs include liberal and technical professional education objectives. In this case, the term liberal connotes those objectives of education attained from coursework in both general education and the major field of study. One of the liberal education outcomes of professional education is contextual competence (Stark, 1987; Stark & Lowther, 1989; Stark, Lowther, & Hagerty, 1986).

Curriculum Coherence

A coherent curriculum has clear and explicit goals and fosters integrated understanding in a “public, accredited, curricular space” rather than through the “private initiative” of the students (AAC, 1992). A coherent curriculum involves connections among courses within the major and across the disciplines, and can be discerned through examination of the detailed syllabi and course plans of an academic program (Stark, 1986, p. 434). A coherent curriculum is the result of an intentional design by faculty across the disciplines responsible for education throughout the four-year baccalaureate degree.

Organization of the Dissertation

This dissertation is presented in five chapters. The first chapter introduces the problem, describes the purpose and plan for the study, and explains the study’s significance and limitations. It includes the research questions and a definition of key terms.

Chapter 2 is a summary of the literature on the following topics: the nature of engineering knowledge and its relationship to contextual competence, the history of the role of socio-humanistic studies in the engineering curriculum, the problem of curriculum coherence and efforts to find the common ground between general education and the major, and the differences in the educational goals of faculty members in engineering and the humanities and social sciences. The chapter concludes with a discussion on the relationship between the goals of professional, general, and engineering education.

Chapter 3 contains a description of the research methodology used in this study. It includes the rationale behind the selection procedures for the study site and faculty participants, a description of the selection procedures and their outcomes, the procedures for data collection and analysis, and the procedures for verification of the study results.

The results of the data analysis are organized by research question and are presented in detail in Chapter 4. Chapter 5 provides a summary overview of the findings, a discussion of the major conclusions of the study, and recommendations for further study.

Approvals

This study was approved by the Institutional Review Boards at the University of Georgia and the study site, the Georgia Institute of Technology. The following IRB approvals apply to this study: Human Subjects Office, University of Georgia, Project Number H2004-10430-0; and Office of Research Compliance, Georgia Institute of Technology, Protocol Number H04007.

CHAPTER 2

REVIEW OF THE LITERATURE

Overview

The development of contextual competence in the undergraduate engineering curriculum requires faculty members in engineering to broaden their educational agenda to include purposeful connections between coursework in general education and the major. The literature review conducted for this study explores the concept of contextual competence in the epistemology of engineering knowledge and its expression in the engineering curriculum. The review provides insight into the faculty perceptions of the importance of contextual studies to the formal education of an engineer, and explanations for the differences in perceptions held by faculty from different disciplines. The literature review is organized into five sections:

Contextual Competence and Engineering Knowledge

The literature in the first section was drawn from the areas of history of technology and sociology of technology. The purpose of this section of the review is to describe the nature of engineering knowledge and the role of values and context (contextual competence) in the practice of engineering. It also establishes a foundation for understanding the content and structure of the undergraduate engineering curriculum and the enduring debate over the contribution of coursework in the humanities and social sciences to it.

Contextual Competence and the Engineering Curriculum

The literature in the second section was drawn from the national reports on the status of engineering education. The purpose of this section is to provide an historical perspective on the humanities and social sciences in the engineering curriculum as seen through the eyes of engineering educators. The reports reveal an increasingly sophisticated understanding of the need for socio-humanistic studies in the engineering curriculum, but this need is countered by pressure to increase the scientific content within the four-year baccalaureate degree, and indifference, even hostility, among the faculty members in engineering and the humanities and social sciences toward improving the coherence between their respective parts of the curriculum.

Curriculum Coherence and Efforts to Identify the Common Ground

The third section of literature was drawn from several national reports on undergraduate education. This section places the debate over the humanities and social sciences in the engineering curriculum into the context of a broader national debate over coherence in the undergraduate curriculum. In particular, it examines the movement to redefine the concept of liberal education for a technological society. These “new liberal arts” proponents argue that liberal and professional education programs (such as engineering) share many objectives in common, and this common ground constitutes an opportunity to improve coherence in the undergraduate curriculum.

Differences in the Disciplines and Educational Goals of the Faculty

The literature in the fourth section was drawn from the fields of psychology and sociology of education. The purpose of the literature reviewed in this section is to provide insight into the reasons behind the tension between faculty in engineering and the humanities and social sciences over curricular matters. The literature includes research on the disciplines and how differences in the disciplines are related to differences in educational objectives and evaluation methods. It also includes several studies on faculty attitudes toward educational objectives such as contextual competence. In particular, these studies provide insight into the attitudes of engineering faculty toward coursework in the humanities and social sciences and its relevance to the development of contextual competence in engineering education.

The Common Ground between General Education and Engineering Education

The final section of the literature review describes the undergraduate engineering curriculum as it is structured at the study site, the Georgia Institute of Technology. The purpose of this section is to explain the relationship between the nature of engineering knowledge and the objectives of general education, engineering education, and professional education. This section ties together the literature presented in the first four sections and sheds light on the considerable overlap in objectives shared between general education and the engineering major. Contextual competence is one of those shared objectives.

Contextual Competence and Engineering Knowledge

The most common misconception about engineers is that they are practitioners who apply general theories developed by scientists to the solution of a particular problem and, through mundane and “intellectually uninteresting” processes, make something that somebody wants or needs (Vincenti, 1990, p. 3). In this sense, engineering knowledge is merely *applied* scientific knowledge and an engineer is an applied scientist. If this is true, then what type of knowledge underpinned the development of technology prior to the scientific revolution of the 17th century? What type of knowledge allowed those outside the sphere of the scientifically literate to be technologically innovative well into the 19th century? Historian John Staudenmaier (1985) argues that, in the absence of modern scientific knowledge, some form of knowledge was needed to transform societal needs and contextual considerations through technical design into artifacts. To Staudenmaier, the essence of what an engineer knows and does arises from the *tension* between context and technical design, with this tension defining the nature of technology and the engineering design process. Hence, engineering knowledge is more complex than just applied science; it involves the application of science and the scientific method in a creative process through which the design of an artifact is *socially constructed*. From this constructivist point of view, engineering includes a broader set of values and skills that are used to define a problem and negotiate the design of an artifact to address it (Staudenmaier, 1985).

The Nature of Engineering Knowledge

In his treatise on the epistemology of engineering design, Walter Vincenti (1990) describes engineering as a "problem-solving" activity. He portrays technological innovation as the engineer's response to the wide variety of problems arising from the contextual needs and desires of society (Vincenti, 1990, pp. 200-203). For the engineer, problem-solving is "almost synonymous" with design, with the design process encompassing a series of interrelated design problems at different levels of complexity. At the higher levels of design, both technical and non-technical contextual issues strongly influence the nature and desired functional characteristics of the technology. In organizing his work, the engineer reduces the design problem into "manageable subproblems" of decreasing levels of complexity. These lower-level design subproblems are highly structured and better defined in terms of the system's goals and practical requirements. At the lower level, the non-technical contextual influences are weaker and less direct, allowing the engineer to focus on the "internal needs of design," or problems that arise within the design of an artifact (Vincenti, 1990, p. 11). At a lower level of design, this tension is a particularly creative force connecting the engineer's abstract, often scientific knowledge to his concrete knowledge of the demands of the design for the artifact. Using Staudenmaier's (1985) framework, the engineer's creativity translates into forms of technological knowledge, which he places into four categories: scientific concepts, problematic data, engineering theory, and technical skill.

Scientific Concepts. Staudenmaier distinguishes between exogenous science, or science as an external reservoir of knowledge available to the engineer, and indigenous science, the science learned as part of engineering education that has been “appropriated and restructured according to the specific demands of the design problem at hand” (Staudenmaier, 1985, p. 104). Vincenti includes scientific concepts under the broad category of theoretical, and highly abstract, tools that engineers use when thinking about design. From the exogenous science pool, engineers draw upon mathematical formulas for quantitative analysis or the analytic geometry of Descartes. They use basic concepts from the sciences such as force and mass from Newtonian physics, as well as mathematically structured physical information adapted from the sciences for a particular application, such as the physics and chemistry of gases used for solving problems in high temperature gas dynamics (Vincenti, 1990).

Problematic Data. For the engineer, the range of options available for the design of an artifact is constrained by the material and societal contexts; in other words, the contexts create particular technical problems for the engineer to solve. The unique knowledge and data the engineer generates to solve such problems constitute another form of technological knowledge. “The conceptual content of the data being sought necessarily reflects the structural design of the technology that has called it forth” (Staudenmaier, 1985, p. 107). This characteristic of technological knowledge, which Staudenmaier calls “problematic data,” applies to two forms of knowledge included in Vincenti’s typology. The first is “criteria and specifications.” With the general goals of a desired technology in mind, the engineer develops concrete objectives and translates them into “specific, quantitative goals couched in concrete technical terms” (Vincenti, 1990, p. 211). These design criteria and specifications include the technical criteria appropriate to a particular technology and its use (or to a general class of technologies and conditions to which they apply) and the numeric values or limits (also known as specifications) the engineer assigns to the particular technology of interest.

The second form of knowledge is “quantitative data,” or the information about physical properties and quantities that the engineer derives empirically or calculates theoretically. Quantitative data can be descriptive or prescriptive. Descriptive data represent the engineer’s “knowledge of how things are” and include physical constants, properties of substances and physical processes (such as reaction rates) and operational conditions. Prescriptive data represent the “knowledge of how things should be to attain a desired end.” These data include parameters set for performance or safety and other engineering standards (Vincenti, 1990, pp. 216-217).

Engineering Theory. Engineers use the theoretical and experimental methods of science to develop abstract and universal technological knowledge related indirectly to solving specific technical problems. Staudenmaier defines this knowledge as “engineering theory,”

> a body of knowledge using experimental methods to construct a formal and mathematically structured intellectual system. The system explains the behavioral characteristics of a particular class of artifact or artifact-related materials (Staudenmaier, 1985, p. 108).

Engineering theory enhances technological design through the use of quantitative methodology and precision, distinguishing theory-based engineering practice from mere skill. Because of its practical orientation, the content and experimental procedures of engineering theory are structured by the nature of the specific technical problems they are intended to address.

In Vincenti’s scheme, engineering theory includes theoretical tools and two fundamental design concepts, the operational principle and normal configuration. As a form of “systematic technology,” these theoretical tools are based on scientific principles and involve some sort of approximation associated with a particular situation. While lacking in scientific rigor, they have explanatory power and are used because they work. They may apply to a particular class of phenomenon, such as the use of control volume in fluid mechanics, or a particular device, such as the use of elementary beam theory in estimating the adequacy of materials. In some cases, they employ *ad hoc* assumptions that allow for rough approximations of complex phenomena, such as turbulent flow, whose behavior is beyond exact calculation (Vincenti, 1990). Vincenti's inclusion of fundamental design concepts fills a gap in Staudenmaier's framework. These design concepts form a stock of technological knowledge that engineers use as a basis for normal design and as a point of departure for radical design (Vincenti, 1990).

Technical Skills. Engineering knowledge is intimately associated with practice, and its extension to the building of artifacts requires technical skills. Staudenmaier defines two types of skills that the engineer learns experientially in the workplace, one is physiological and associated with the use of particular tools or machines, and the other is intuitive and related to making technical judgments based on experience. In the history of technology, such skills have been passed from the master to the apprentice in the workshop (Staudenmaier, 1985). Over time, associations or guilds of craftsmen organized these skills into bodies of knowledge (or "rules of thumb"), allowing the skills to pass to future generations or to craftsmen in distant places (Calvert, 1967, p. 7). Vincenti discusses the tacit nature of such skills and how they differ from the precise and codifiable tools of engineering theory and science:

> Designers also need for their work an array of less sharply defined considerations derived from experience in practice, considerations that frequently do not lend themselves to theorizing, tabulations, or programming into a computer. Such considerations are mostly learned on the job rather than in school or from books; they tend to be carried around, sometimes more of less unconsciously, in designers' minds. Frequently they are hard to find written down (Vincenti, 1990, p. 217).

The ability to execute an entire engineering process is another form of engineering knowledge. Engineering requires what Vincenti calls “design instrumentalities,” the structured procedures, ways of thinking, and judgment skills the engineer uses to *do* his work. In the course of a design, an engineer decides how to structure the problem into manageable subproblems, determines whether a solution to a problem should be optimal or satisfactory, and employs iterative techniques to achieve successive improvements to the design. He or she may also have a “feeling for the elegance and aesthetics” of the design. The engineering way of thinking requires the language of science and mathematics for analysis and nonverbal forms of communication for creativity. The engineer translates his “visual thinking,” his imagination and intuition, into analogies, graphs, sketches, drawings, and models. These nonverbal ways of thinking and communicating “provide shared ways for apprehending the operation of a device and imagining the effect of alterations in its design.” Vincenti argues that this type of thinking is tacit and can be learned only through practical experience (Vincenti, 1990, pp. 220-222).

Contextual Competence and the Engineering Curriculum

When an engineer defines a problem, he integrates his technical knowledge and skills with his understanding of the larger societal and physical contexts in which the problem is presented and defined. The engineer’s interpretation and solution of the problem involve judgment bounded by technical constraints and shaped by his personal values and experience and those values held by the broader society. Codes of ethics, standards of conduct, safety and environmental standards, all express the societal values that guide the work of the professional engineer. The engineer’s values, as well as his technical knowledge, constitute an important aspect of professional engineering practice. As a consequence, the objectives of professional engineering education include competencies that are technical, professional, and liberal in nature, developed through a curriculum that combines both liberal education and specialization in the major field of study. This particularly American form of engineering education reflects a century of debate about the appropriate role in the academy of professional engineering education and its utilitarian and vocational values, and the challenges associated with fitting a professional engineering curriculum into a four-year baccalaureate degree. The result is a combined curriculum of general and professional studies encompassing the range of knowledge, skills, and values considered essential for a professional engineer as a learned individual.

History of the Integrated Engineering Curriculum

The modern American engineering curriculum is the result of an ongoing dialogue among academic and practicing engineers on what an engineer should know and how he or she should learn it. For nearly 100 years, the *collegiate* engineering curriculum has defined the membership criteria for the profession of engineering through the selection of content, methods, and contextual experiences that translate school-based knowledge into what Layton calls the "common denominator" of technology: the ability to design (Layton, 1974, p. 37). The academic engineers shaping the American engineering curriculum have drawn upon and adapted practices from England, France, and Germany and grafted them onto a particularly American form of higher education. Recognizing that engineering knowledge is inseparable from its ultimate use, the faculty consulted the practicing engineers in industry who hire their graduates. This collaborative effort between academic and practicing engineers depended on the willingness of the colleges to compromise between the liberal education values of the academy and the vocational values of the workplace. The desire to establish engineering and engineering education as a learned profession compelled both academic and practicing engineers to define a form of technical education that fit into an existing structure for baccalaureate education. An examination of the history of the American collegiate engineering curriculum reveals a constant struggle to balance the liberal education values of the academy with the vocational values of the workplace. The result is a combined curriculum of general and professional studies encompassing the range of knowledge, skills and values considered essential for a professional engineer as a learned individual.

The roots of the integrated general studies-engineering curriculum can be traced to a collegiate tradition dating from the colonial period, and subsequently transformed by scientific culture and the demand for "useful arts" in the 19th century. The faculty in the colonial colleges imported a curriculum from England that emphasized cultivating mental discipline through the study of Latin and Greek and recitation of the classic texts. In Colonial America, the classical curriculum provided a common social and intellectual experience that fostered "desirable class loyalties" among a tiny social elite who would lead an emerging nation as religious and government leaders, or practice in the learned professions (Veysey, 1973, p. 162). At the turn of the 19th century, the survival of the American republic depended on economic growth and many believed that the "useful arts" would provide a means to preserve liberty and prosperity (Oldenziel, 1999, p. 20). Early attempts to incorporate more utilitarian studies into the colleges, such as Thomas Jefferson's plan to promote agriculture, manufacturing, and commerce at the University of Virginia, marked a significant change in the nature of utility in higher education from education for self-culture to education for practical advantage (Guralnick, 1975; Miller, 1988). While the "useful arts" would allow a man to "improve himself and his chances for the future," the leaders of the academies and colleges believed that ascendancy of the middle class also depended on a liberal education (Sinclair, 1972, p. 251). The compromise was to introduce science into the classical curriculum, in some cases as part of a non-degree or partial course of instruction, and in others as part of a parallel course of instruction leading to a degree (Rudolph, 1962).

At the same time, scientific culture reached into the workplace, propelling shop engineers and mechanics to develop a more formal system of technical training through mechanics institutes, lyceums, and apprentices' libraries (Sinclair, 1972). Between 1820 and 1850, the mechanics' movement offered an alternative form of education through their "mutual improvement associations" in the northeastern United States. Organized to promote the "mutual encouragement and aid in the great enterprise of mental, moral, scientific, and social improvement," the Mechanics' Association of Maine typified the educational and professional objectives of the mechanics' associations during this period. For the members, social mobility would be achieved through temperance, morality, cleanliness, and industry (Calvert, 1967). Rejected by the philosophical and scientific societies, the members not only distrusted scientific education in the classical curriculum, they also questioned the value of classical education at all for the engineer. One editorial in the <u>Mechanics' Mirror</u> expressed the mechanics' skepticism of the utility of scientific training in the colleges:

> Shall mere scientific men, and not operatives, be the high priests who shall explain the laws and teach the principles which direct our respective mechanical callings? (Calvert, 1967, p. 36).

The mechanics' disregard for college professors was not irrational; most technological advances owed little to science in the first half of the nineteenth century. Nonetheless the "proto-industrial economy" created new science-oriented jobs for college-educated analytical chemists and geologists employed by the mining industries. Chemistry and geology professors routinely took part in government- and private- sponsored exploration and exploitation of the mineral reserves in the west. The value of science education in these endeavors contributed to a growing awareness that a college education could contribute to “greatness and economic prosperity on a national level and socioeconomic advancement on the personal” (Guralnick, 1975, p. 147). In return, the growth in the national economy allowed for increasing levels of philanthropy, especially from many industrialists who gave scientific instruments and libraries to the colleges.

After the Civil War, the implementation of the 1862 Morrill Act stimulated the creation of new state universities, funded by land grants to the states for education directed toward “such branches of learning as are related to agriculture and mechanic arts . . . without excluding other scientific and classical studies and including military tactics.” The purpose of these land-grant institutions was to promote both liberal and practical education for the industrial class (Ross, 1942). Faced with increasing competition from the land-grant colleges and a decreasing pool of students, the classical colleges had serious economic problems (Rudolph, 1977). The need for funding hastened the incorporation of applied sciences in the colleges who sought land-grant funds and donations from wealthy industrialists “ready to attach their names and their fortunes to the development of schools of applied science.” The classical colleges readily accepted these donations and avoided “contamination” by creating affiliated schools of applied science rather than establishing courses in applied science equivalent to the classical courses of study (Rudolph, 1977, p. 103). With the demise of the politically and socially weak mechanics’ organizations by the 1870s, the land-grant colleges and some of the classical colleges offered school-based engineering education as the preferred form of training for a professional engineer (Calvert, 1967).

Throughout the 19th century, proponents of technical education debated whether or not to affiliate engineering programs with the colleges and their liberal arts-based degree programs (Calvert, 1967; Emmerson, 1973; Sinclair, 1972). By 1880, the colleges and state universities shared equal responsibility for educating professional engineers with the mechanics and engineers on the shop-floor (Reynolds & Seely, 1993). With this increase in standing in the educational community, technical educators began to seek parity with other faculty in the colleges, forming an interest group with its own professional aspirations and values (Sinclair, 1972). By 1890, the time had come for the leaders of the key engineering institutions in the country to break with the traditions of shop-floor training and to legitimize engineering as an academic discipline and profession by linking it with science (Oldenziel, 1999). Engineering faculty developed new values of professionalism around a scientific ethos and organized themselves into research disciplines in the tradition of the German research university (Light, 1974). In the context of engineering education, the emergence of these new professionals culminated in the drive to establish credentials in the engineering profession (Lundgreen, 1990; Oldenziel, 1999). Especially in the new science-based industries, engineers assumed a new "technical-managerial" function, positioned between top management and the shop floor and distinguished from the shop-trained mechanics by scientific and mathematical knowledge (Oldenziel, 1999, p. 78; Sinclair, 1972, p. 261). Near the close of the 19th century, engineering faculty and practitioners in industry advanced their mutual professional interests through membership in combined professional engineering societies, proposing college-based engineering education as the basis for establishing the credentials for professional engineers (Hughes, 1983; Lundgreen, 1990; Noble, 1977; Oldenziel, 1999).

The Humanities and Social Sciences in the Engineering Curriculum

For over a century, reports on the status of engineering education have emphasized the importance to the profession of values and contextual perspectives developed through coursework and practice in engineering and science complemented by studies in the humanities and social sciences. These reports reflect a national consensus on the objectives of engineering education, based on the participation of thousands of academic and practicing engineers in surveys conducted by national engineering organizations. For the most part, the participants in these surveys believed that such values and perspectives would be developed through practice under the supervision of exemplary engineering faculty, and through limited coursework in the humanities and social sciences. Over the years, the recommendations in the reports display increasingly sophisticated views on the role of such courses in the curriculum, and the way in which learning from them should be integrated with technical studies.

The Mann Report (1918). The first report on engineering education raised the profile of liberal education in the undergraduate engineering curriculum by making the controversial recommendation that *more* emphasis be placed on character and culture studies than on purely technical and scientific studies (Mann, 1918). The Mann study followed the creation of the Society for the Promotion of Engineering Education (SPEE), which held its first meeting at the World’s Columbian Exposition in Chicago in 1893 (Grayson, 1993). At this meeting, engineering educators expressed concerns about their status in the academy and the perceived quality of engineering education. Many believed that college-based engineering education not only presented a comparable form of education to that in the liberal arts college, but also one more suitable for men who would be part of an industrial society. Francis A. Walker of the Massachusetts Institute of Technology reflected the sentiment of many engineering educators in a statement made two years prior to this first meeting of the SPEE:

> Too long have we submitted to be considered as furnishing something which is, indeed, more immediately and practically useful than the so-called liberal education, but which is, after all, less noble and fine. Too long have our schools of applied science and technology been regarded as affording an inferior substitute for classical colleges. Too long have the graduates of such schools been spoken of as though they had acquired the arts of livelihood at some sacrifice of

> mental development, intellectual culture, and grace of life . . . . I believe that in the schools of applied science and technology is to be found the perfection of education for young men (Noble, 1977, p. 25; F. A. Walker, 1891, p. 206).

Heralded as the "acceptance of the college as the locus of professional training for engineers," this formal organization of engineering educators assumed a coordination and communication role in the engineering community (Reynolds & Seely, 1993, p. 136). The SPEE provided a forum for engineering educators to balance the conflicting demands of liberal and professional education, and attain a national voice and status for engineering as a profession (Grayson, 1993; Reynolds & Seely, 1993).

By the turn of the twentieth century, liberal education had taken a new meaning in the education of professional engineers. The engineering curriculum provided sufficient mathematics and scientific studies to achieve a comparable level of mental discipline desired from a liberal education. What it lacked, however, was *culture*. As a leader of a corporation, an engineer needed those "higher social qualities that make for leadership"—otherwise known as culture and polish. At the very least he needed agreeable manners and tact (Atkinson, 1907, p. 230). In 1897, the president of the Society for the Promotion of Engineering Education lamented the reduction of "culture studies" in the engineering curriculum since he believed that such studies were essential to professional success:

> To ensure large success he [the engineer] must be a man of broad culture. He is to direct large enterprises as well as plan the necessary structures and machinery of the plant; and that man will succeed who, by the influence of his personality with tongue and pen, shows himself able to hold his position as the peer of other great organizers of our industrial life. The highest success is to be quickly reached as a rule only by those engineers who have had adequate preliminary education in culture studies, which is another name for the liberal arts" (Eddy, 1897, p. 14).

Said another engineering professor, “Music may be as far from an engineer’s requirements as any subject; but is it not conceivable that, not to mention its usefulness as a recreation, it might often help an engineer socially and this aid him professionally?” (Chatburn, 1907, p.224)

Dugald Jackson, the chief engineer at General Electric Company and head of electrical engineering at MIT, served as the SPEE president from 1906 to 1907. Under his leadership, the SPEE conducted the first national study on the status of engineering education. The Carnegie Foundation for the Advancement of Teaching funded the study and appointed as its leader a physicist from the University of Chicago, Charles Mann. In a subsequent report for the Society, Jackson reflected on the Mann study, stating that the Carnegie Foundation had assumed “a paternal interest” in the study and had appointed Mann as an “impartial investigator to make an independent report.” Mann’s report aroused considerable debate among engineering faculty, in part because of the author’s position “outside the circle of engineering schools.” While the engineers acknowledged the validity of many of Mann’s conclusions, they dissented strongly to the report because his findings were “so frankly expressed as to be almost brutal in outspokenness” (Jackson, 1941, p. 21).

What had Mann revealed in this report? As part of the study, Mann asked the members of four engineering societies to rank, in “order of importance for success in engineering,” the qualities of character, judgment, efficiency, understanding of men, knowledge, and technique. Of the 7,000 respondents, 94.5% ranked character the highest and placed technique “last by an equally decisive majority.” Mann emphasized “the importance of teaching technical subjects so as to develop character, the necessity for laboratory and industrial training throughout the courses, and the use of good English” (Jackson, 1941, p. 19-20). In the first national report on engineering education, Mann recommended that the engineering curriculum place more emphasis on character development, through the study of culture and values, over mastery of technical material (Reynolds & Seely, 1993). The emphasis on character development in Mann's report may have undermined the aspirations of the engineering educators who sought legitimacy for engineering as a discipline in higher education.

The Wickenden Report (1930). The Wickenden Report (1930) enhanced the significance of non-technical studies by calling for a unified curriculum that engaged students in technological and humanistic studies as part of a coherent and integrated program. The call for balance and coherence in the curriculum reflected the engineering community's response to what one engineering leader called "a period of general dissatisfaction and criticism of various types of education" in the country following World War I (Scott, 1930, p. 92). This trend would continue through the Second World War.

The SPEE created a formal Board of Investigation and Coordination in 1923 to respond to the findings of the Mann Report and to improve the overall status of engineering education following World War I. SPEE President Charles Scott organized another study and appointed William Wickenden, a vice president at AT&T and former faculty member at MIT, to lead it (Scott, 1930). Reflecting on the study experience, Scott noted the difficulty in defining the concept of an "engineering curriculum" for the wide range of institutions offering engineering degrees:

> It was found to be quite difficult to formulate the problem definitely. The construction of the curriculum had been initially selected as a definite objective, but even then one must know the purposes for which the curriculum exists, the quality and objective of the students, and their purposes in becoming engineering graduates, as well as the abilities and experiences of the teachers who are to administer the curriculum (Scott, 1930, p. 93).

The Wickenden study was comprehensive, including information and recommendations from more than 700 faculty members organized into local committees at 150 engineering schools. Coordinated by the New York office of the National Engineering Societies, the study included data on curricula, admissions policies, retention rates, and degrees conferred; students, graduates, and teaching personnel; engineering school research, graduate study, and educational costs; and attitudes of employers toward the curriculum (Reynolds & Seely, 1993). As in the Mann study, the Wickenden study solicited input from over 6,200 members of engineering societies and engineering graduates on the "general qualities most desirable in engineering curricula." The engineers who responded to the survey recommended (1) moderate diversity in the curriculum, but tending away from specialization; (2) emphasis on scientific and broad technical content; (3) inclusion of a well-identified core of required subject matter in common; (4) inclusion at all stages of subjects of purely cultural value; (5) due emphasis on the economic aspects of engineering and on its concern with administration and management; (6) coherence of arrangement and coordination of related subjects; and (7) thoroughness rather than completeness of detail (Jackson, 1941, pp. 27-30; Wickenden, 1930, p. 1247).

With the Wickenden Report, the SPEE acknowledged for the first time the unlikelihood of expanding the curriculum beyond four years and presented instead a compromise between academic and professional study (Reynolds & Seely, 1993). The authors concluded that engineering education should be more holistic, a "self-contained branch of higher education" in which the student engaged in technological and humanistic studies as part of a coherent and integral program. The authors contrasted the "unified" curriculum with the more common two-part curriculum consisting of a pre-engineering component under separate administration and a purely technical, profession-oriented component in the final years (Jackson, 1941, p. 29; Wickenden, 1930, p. 1253). As a compromise, the unified curriculum would include fewer technical and specialized courses and more economics and humanities courses.

The comprehensive nature of the Wickenden study enabled the engineering community to assert a new authority on educational issues in a national forum. Through this study, engineering educators demonstrated the ability to "maintain a conservative balance with a progressive vision" while attempting to clarify and improve the goals, values, and methods of engineering education. In terms of defining and assessing educational goals, President Scott believed that the engineering schools were superior to the liberal arts colleges:

> No other group of teachers, it may be confidently said, has done this in as thorough a manner, and no other group of teachers has formulated so definitely its ideas in these essential points. Colleges of liberal arts, offering varied programs of studies, have never given such strict attention to the result they hope to accomplish or the means by which it is to be accomplished because their objectives lack the definiteness which gives form to the engineering curriculum and the educational needs of the graduate engineer (Scott, 1930, p. 97).

As further demonstration of their seriousness and commitment, the authors of the Wickenden Report recommended the creation of a new agency to set standards for curricula and to implement a process for inspecting the engineering schools for conformance. In 1932, a joint effort of the SPEE, engineering schools, professional engineering societies, and state licensing boards resulted in the creation of the Engineers' Council for Professional Development (ECPD). The ECPD approved its first four-year engineering program in 1935 at the Stevens Institute of Technology (Grayson, 1993).

The Jackson (1941) and Hammond Reports (1940 and 1944). The reports issued during World War II provided a new set of terms for talking about complementary studies in the engineering curriculum. It suggested that the "scientific-technological and humanistic-social stems" of the curriculum should operate in parallel throughout the four-year degree (Hammond, 1940; Hammond, 1950). In the first half of the twentieth century, educators were concerned not only about the engineering student’s ability to understand global issues, but also about his ability to lead in a post-war society dominated by technology.

World Wars I and II dramatically influenced the aims and scope of engineering education for the remainder of the twentieth century. The increasingly technical nature of war required more engineers for the battlefield as well as industry. In response, the engineering schools developed a direct relationship with the federal government for training and development of military personnel, and research and development of military technologies (Armsby, 1944; Keller & Pyle, 1942). The influx of research money suited the desires of engineering faculty interested in developing the discipline of engineering and enhancing their professional prestige through the addition of graduate engineering education programs.

In 1941, the SPEE released another report on the status and trends of engineering education. Authored by former president Dugald Jackson, the Jackson Report drew upon data from a survey of 679 engineering curricula in 136 institutions conducted by the ECPD between 1935 and 1938. In earlier reports on the status of engineering education, the authors lamented the lack of research activity and credentials among faculty in the engineering schools. By 1941, Jackson noted the change in the role of research from “a backward position to its proper place of equality” with teaching and engineering practice. This shift had serious implications for the balance in teaching, research, and engineering practice in the schools. While Jackson acknowledged that research activity “may be to the sacrifice of attention to both teaching and practice,” he suggested that the engineering faculty develop a “professional engineering attitude” and increase their contact with professional engineers and industry by joining professional engineering societies and attending conferences (Jackson, 1941, p. 143).

Jackson viewed engineering as “a structure which bridges the gulf between the impersonal exact sciences and the more human and personal affairs of economics and sociology; by means of which bridging, engineering makes the sciences serviceable to society in both physical and economical ways” (Jackson, 1941, p. 12). As such, the curriculum had to balance studies in science and engineering with those in the humanities and social sciences. Before Jackon’s report, liberal education in the engineering curriculum meant coursework in history (U.S. history or government), economics (practical engineering economics), English (writing and readings in social and cultural studies), and electives with little perceived relevance to the engineering profession. The goal was to include some non-technical coursework that would help the students develop better reading and writing skills and, if possible, expose them to topics that would inspire a “life-long appreciation for general or liberal studies” (Adams, 1996, p. 173). Reflecting on the latter part of the nineteenth century, Jackson observed the “tremendous growth of the recognition of science in its various aspects” and the increasing amount of time the engineering schools devoted for instruction in the sciences. While he supported calls for the “enrichment of engineering education,” Jackson believed that proposals for broadening the curriculum should be guided by “pedagogical tenet” and that little would be accomplished in the climate of “hysteria” that often accompanied such proposals (Jackson, 1941, pp. 16-17).

In the decades between the World Wars, faculty members of all disciplines expressed concern over the ability of students to comprehend the larger social issues that result in war. Many universities experimented with general education courses aimed at developing the students’ understanding of contemporary issues in the larger social and historical contexts. The increasing popularity of engineering programs brought significant attention to the breadth of studies in humanities and social sciences in the engineering curriculum. One historian at the time argued for a “more utilitarian” aim in history courses, especially for engineering students whom he believed lacked a sense of responsibility and leadership in world affairs:

> Many of the problems that confront the world today await the application of engineering techniques and principles, but the present narrow training of the engineer ill fits him to cope with them. The engineer of tomorrow should have more than a mastery of the principles of his chosen field. If he is ever to become an effective leader his training and interests must be of much broader scope (Davis, 1944, p. 99).

Such concerns resonated with professional engineers. In 1940, the New York office of the National Society for Professional Engineers, which had supported previous SPEE studies, sponsored a bill in the New York legislature that would require two years of liberal arts training for licensing and registration of professional engineers (Reynolds & Seely, 1993). In response, the SPEE attempted to clarify the objectives of general education in the engineering curriculum through two reports developed by Harry Hammond, the dean of engineering at Pennsylvania State University and associate director of the Wickenden study. Hammond’s study did not collect new data and did not solicit extensive participation by the engineering schools. The Hammond Reports reiterated and expanded on the recommendation in the Wickenden Report for a more holistic curriculum. Hammond divided the curriculum into two parallel and integrated stems: the scientific-technological stem and the humanistic-social stem (Reynolds & Seely, 1993). The humanistic-social stem of engineering education focused on competencies students would gain through courses in the humanities and social sciences. The humanistic-social studies would be part of a “designed sequence of courses extending throughout the four undergraduate years” and would not include business or other professional subjects (Adams, 1996, p. 173; Hammond, 1940, p. 555). Through such studies, students would develop

1. an understanding of the evolution of the social organization within which we live and of the influence of science and engineering on its development

2. the ability to recognize and make a critical analysis of a problem involving social and economic elements, to arrive at an intelligent opinion about it, and to read with discrimination and purpose toward these ends
3. the ability to organize thoughts logically and to express them lucidly and convincingly in oral and written English
4. an acquaintance with some of the great masterpieces of literature and an understanding of their setting in and influence on civilization
5. the development of moral, ethical, and social concepts essential to a satisfying personal philosophy, to a career consistent with public welfare, and to a sound professional attitude
6. the attainment of an interest and pleasure in these pursuits and thus of an inspiration to continued study (Hammond, 1940, pp. 555-556)

Following his report, Hammond continued to examine the role of liberal arts in engineering education. By 1950, the typical engineering curriculum was composed of one-third math and sciences, one-sixth humanistic-social studies, and one-half technological studies—in other words, one-half of the engineering curriculum was provided by faculty in the liberal arts and sciences. The curriculum was arranged such that the faculties of arts and sciences and of engineering had to coordinate their efforts, progressing from fundamental sciences and mathematics, to applied science, and then to the use of the principles in problems of engineering practice. Referring to his earlier reports in which he recommended reducing the technical subjects to make room for more science and humanities, Hammond discussed the need “for courses of the soundest and best sort in the schools of liberal arts.” Engineering faculty, he argued, would assume an attitude of "look before you leap" before replacing the professional engineering courses with liberal arts courses. Because the engineering student was expected “to work hard and effectively in whatever field of subject-matter” he studied, Hammond asked the liberal arts faculty to strive to develop, in the students, “the sound habits of thought and work that they must form if they are to become successful engineers.” At the very least, the integration of the engineering curriculum would be enhanced if the non-engineering faculty would develop an "understanding and appreciation of the points of view, interests, and background of engineering students" (Hammond, 1950, pp. 190-193).

> If such an understanding is sensed by the students, they can be led to do almost anything that liberal arts teachers may desire them to do. For the engineers are a competent group and, in general, they are receptive to new ideas and points of view, especially if these strike them as significant in or related to their professional careers (Hammond, 1950, p. 193).

The Grinter Report (1955). The dominant concern about scientific literacy and technological superiority in the post-Sputnik period of the cold war is reflected in a report on engineering education that shaped the content and form of the curriculum for over forty years (Harris, 1994). The Grinter report recognized the increasingly central role played in engineering by science and the scientific method and recommended increasing coursework in science and engineering theory in the curriculum. This effectively reduced the time available in the curriculum for humanities and social science courses and, implicitly, reduced the perceived importance of such courses to educating the professional engineer.

The Grinter Report established the template for the current ABET criteria for engineering education. The Grinter study team believed that the post-war climate demanded men who could "face new and difficult engineering situations with imagination and competence." The modern engineer as opposed to an artisan or craftsman, argued Grinter, must be able to transform and apply the basic laws of science by applying mathematical analysis to physical situations.

> Engineering was an art until it applied the methods of mathematics, physics, and chemistry and merged these sciences with engineering art in a professional way to provide for the convenience and welfare of the public (Grinter, 1954, p. 258).

The Grinter Report's recommendations for the engineering curriculum reflected the importance of science, mathematics and engineering theory for modern engineering practice. Prior to publication of the official report, Grinter explained that ethics and professional responsibility would be developed through interaction with exemplary faculty members:

> Through such experiences and under the guidance of those who have themselves carried responsibility, the student will begin to sense his coming accountability for operating in the framework of society for the general good and in the highest traditions of his professional group. The teacher who stimulates such a sense of professional responsibility in his students is a great teacher, deserving of the applause of his university and of his profession (Grinter, 1954, p. 261).

In addition to the detailed "engineering-science" recommendations, the report described the broad goals for the development of leadership, professional ethics and general education, thereby explicitly integrating general education into the engineering curriculum. The Grinter report recommended that the engineering curriculum should

1. Strengthen work in the basic sciences (math, chemistry, physics)
2. Include six engineering sciences to be taught as a common core of engineering curricula
3. Develop an integrated study of engineering analysis, design, and engineering systems designed to stimulate creative thinking
4. Include elective subjects for the students' sake and society
5. Assure a continuing, concentrated effort to strengthen and integrate work in the humanistic and social sciences into engineering programs so that the student develops
    a. an understanding of the evolution of society and of the impact of technology on it
    b. an acquaintance with and appreciation of the heritage of other cultural fields
    c. a personal philosophy which will insure satisfaction in the pursuit of a productive life
    d. a sense of moral and ethical values consistent with the career of a professional engineer (Grinter, 1955, pp. 25-63)

The Burdell Report (1956). In spite of the specific recommendations for general education, many believed that the Grinter study did not address adequately the humanistic-social stem of the curriculum (Reynolds & Seely, 1993). In response, Edwin Burdell conducted an elaborate study involving campus site visits and case studies intended to identify the most significant issues associated with incorporating humanistic-social studies into the engineering curriculum. The Burdell Report (1956) identified five problems associated with the philosophy, content, arrangement, administration and credit hours allocated to humanistic-social studies in the curriculum. The report reinforced the recommendations from the earlier Hammond reports and concluded that successful integration of the scientific-technological and humanistic-social stems in the curriculum would require vigorous administrative support for the program, full cooperation and understanding between the engineering and liberal arts faculties, true integration of the studies in the humanities and social sciences with scientific and technical education, and a climate encouraging experimentation with fresh materials and methods. By taking advantage of the "increasing maturity of the student in his upper years," the engineering curriculum could promote true integration during the students' capstone design experience (Burdell, 1956).

The Walker Report (1968) and the Olmsted Report (1968). The last major report of engineering education of its kind, the Walker report (1968), attempted to reverse the trend toward engineering science by acknowledging that both stems of curriculum were vital to the education of an engineer. Walker lamented that the objectives of both the scientific-technological and humanistic-social stems could not be accomplished in the four-year timeframe, and that extension of the curriculum beyond four years was politically impossible. The contextual objectives of the curriculum were addressed in a companion report issued in the same year.

Eric Walker, dean of engineering and later president of Pennsylvania State University, chaired perhaps the most provocative and controversial study of engineering education for the American Society for Engineering Education (ASEE, formerly the SPEE). The Walker study mirrored the Wickenden study in methodology, employing questionnaires and input from local committees on 170 engineering campuses. The report reiterated the recommendations from previous studies on the role of humanistic-social studies and engineering science in the curriculum, and added a new recommendation to improve work in analysis, synthesis, and design (Reynolds & Seely, 1993). Walker and his co-authors believed that general education was as important to the education of a professional engineer as specialized scientific and technological education, and that both contributed to the engineer's ability to solve problems in a "technologically oriented society" (E.A. Walker, Pettit, & Hawkins, 1968, p. 2). The challenge was the limited time available in the four-year curriculum. Walker posed the following question:

> If an engineer is to have the broad general education which his role in modern society demands and at the same time be trained to the high level of proficiency required in many specialized areas of modern technology, how—in the light of the growing demands from both quarters—can the job be done within the confines of the traditional four-year program? (E.A. Walker et al., 1968, p. 2)

In response, Walker made a controversial recommendation, which he called "deliberately provocative" and intended to address the increasingly crowded four-year curriculum. Walker recommended that the master's degree become the point-of-entry into the profession, effectively extending the engineering curriculum to five or more years, and accommodating the needs for liberal studies as well as an increasing amount of scientific and technical content (Reynolds & Seely, 1993). In the preface, Walker acknowledged that the report was not a "consensus report based upon a majority opinion," but was simply "an attempt to indicate, in broad and general terms, the direction which engineering education must take if it is to meet the demands of the future" (E.A. Walker et al., 1968, p. iv).

Walker's recommendations found a receptive audience among other educators concerned about the future of engineering education. William McGlothlin, an expert on professional education during the period of the Walker study, explained how Walker may have developed his controversial recommendations using data collected by the study committee. McGlothlin reported that in 1962 more than 77% of the graduates of engineering programs intended to begin graduate study; nearly 85% of the practicing engineers indicated that they would pursue graduate study if they could repeat their education; over 66% of government and industry managers preferred the master's degree or higher for management positions; and industry and governmental agencies were creating more positions for those with graduate degrees than for those with only the bachelor's degree (McGlothlin, 1969).

McGlothlin concurred with Walker that the four-year curriculum could not possibly accommodate the "dual aims" of technical competence and social understanding. Based on these data, he believed that Walker had sufficient evidence that his recommendation was consistent with commonly held beliefs and values in the engineering community (McGlothlin, 1969, p. 154). The limitation of the four-year curriculum was that it did not provide ample opportunity for the engineering student to develop appropriate values. McGlothlin referenced comments made by Algo Henderson, the former president of Antioch College and director of the Center for the Study of Higher Education at the University of Michigan, who believed that a five-year engineering curriculum should focus on problem-solving and the construction of systems. In this context, McGlothlin believed that engineering education should focus on understanding changes in human values and patterns of behavior to better prepare students to function in an increasingly complex society:

> One of the problems of all of the professions today is to step into the world of tomorrow, an interdependent world emphasizing above all other considerations human values. . . [T]he more complex the society becomes, the more professional men need to define their professional ethics and resolve to fulfill the code (McGlothlin, 1969, p. 156).

A decade later, Walker continued to argue for a concept of engineering education that extended beyond the undergraduate degree. Reflecting on survey data collected for the 1968 report, Walker noted that the types of additional coursework desired by practicing engineers tended to correspond with their age and to their position in an organizational hierarchy.

> This approach [to the analysis of the survey data] produced a very clear pattern: the younger people, those who had just started on their professional careers, found that they needed more science, mathematics, and advanced technical courses. Those who were a few years older felt a need for more study in the areas of management, personal relations, organization, and so on. Engineers in still later years were interested in finance and economics. Later still came the need for political science, history, comparative economic systems and, after retirement, even the classics (E.A. Walker, 1980, p. 220).

Walker concluded that “as one’s circle of influence widens, so does one’s need for liberal studies” (E.A. Walker, 1980, p. 221). The problem was not only the limitation posed by the four-year curriculum, but also the perceived relevance of liberal studies at the time in which such courses would be taken by the engineering student.

> The point is that under no present system of education can a person learn to know all of what is needed for a life of work in a four, six, or seven year college curriculum. Learning is truly a life-long process; and learning is best if it comes as one needs it and not twenty years before or twenty years after (E.A. Walker, 1980, p. 221).

Walker concluded that learning in the liberal arts should be extended throughout an engineering career through continuing education programs for practicing engineers.

Walker faced strong opposition to his recommendation to extend professional engineering education to more than four years from nearly three-quarters of the engineering organizations and over half of the individuals who responded to the preliminary report. The “violent reaction” of the engineering community may have been related to the widening gulf between industry and academic engineers who increasingly responded to federal research mandates (Reynolds & Seely, 1993, p. 143). The reaction to the Walker Report by industry and the professional societies marked an important point of departure for the ASEE and its constituents. The collaborative and respectful climate of past engineering studies was broken, and along with it the ability of the ASEE to speak for all engineers in the academy and in industry. After the Walker Report, the rapid diversification of the engineering disciplines resulted in an expansion of discipline-specific criteria and an increasingly “mechanical” and “quantitative” accreditation process. The humanities and social sciences component of the curriculum went into “stasis,” largely “because the forces aiding and opposing non-technical content were approximately balanced” (Stephan, 2002, p. 13). As such, the Walker Report was the last significant report on engineering education issued by the ASEE.

As in previous reports on engineering education, the Walker Report included a companion report that called for a focus on contextual objectives and the treatment of the humanities and social sciences as “an integral part of a liberal engineering education” (quoted in Adams, 1996, p. 39; Olmsted, 1968, p. 318). The Olmsted Report (1968) included data collected through a questionnaire sent to deans of 185 engineering schools and interviews at 27 schools ranging from small, liberal arts colleges to large, land-grant universities. The survey focused on four questions: What do you see as the purpose of the humanities and social sciences in the education of engineering students? If you could have your way what kind of program would you set up? What are the obstacles to doing this? And what would be a realistic program? (quoted in Adams, 1996, p. 40; Olmsted, 1968, p. 309).

The study found that little had changed in the humanities and social sciences in the curriculum because there was no “coherent vision” for what those changes would entail.

Furthermore, the authors found significant tensions among the faculty members responsible for the two stems of the curriculum:

> The comments which each faculty makes about the other faculty confirm the impression not only of poor communication but of a lack of real understanding as well. One comment says, “They (the liberal arts people) seem unable or unwilling to understand the attitudes of the engineer. They don’t do anything to get through to him.”
>
> On the other hand, the liberal arts people condemn engineering faculty members with equal severity. One dean of liberal arts finds that the chief obstacle to change is “the insistence by engineers on training, on application, and technique.” (quoted in Adams, 1996, p. 40; Olmsted, 1968, p. 312)

Finally, the study concluded that free election allowed engineering students to select humanities and social science courses they found to be useful for the engineering profession, or to select only the introductory courses in a wide range of fields.

The “roots of the problem” with the humanities and social sciences in the engineering curriculum are evident in nearly every national report on engineering education since the first meeting of the SPEE in 1893. Earlier concerns about establishing engineering as a learned profession through combined liberal and professional collegiate education had shifted to concerns about the engineer’s responsibility for the larger impact of technology on society. Ironically, just as the engineering profession was coming to grips with the need to focus on values and context, scholarship in the humanities and social sciences began to take on a scientific aspect, with increasing emphasis on “scientific objectivity and quantification.” As faculties across all disciplines became increasingly professional in their orientation, they developed specialized knowledge and tailored the content of their courses accordingly; one result being a fragmented curriculum that left the engineering student responsible for integrating his learning across the disciplines. The Olmsted report concluded by recommending that learning in the humanities and social sciences take place throughout the four-year engineering curriculum (for example, by increasing the contextual emphasis in engineering courses), and that the faculties work to develop courses that reflected the reciprocal need for humanistic education in engineering and technical education in non-engineering majors (Adams, 1996, pp. 42-46).

Curriculum Coherence and Efforts to Identify the Common Ground

In the three decades after the Walker and Olmsted Reports, engineering education remained challenged by problems of coherence in the curriculum and limited collaboration among the faculties in engineering and the humanities and social sciences. The lack of coherence between the general and engineering components of the curriculum was not unique to engineering, but reflected a larger crisis nationally with the ability of general education to counter the effects of undergraduate specialization (AAC, 1985). Some educators argued for a more adaptive concept of liberal education, one more suited for citizens of a postindustrial society. They argued that the concept of liberal education should reflect the cultural context in which it exists and, since modern society was inextricably intertwined with science and technology, it should expand to include technology-oriented studies for all college students. Such views created new possibilities for collaboration among the disciplines, and hope among engineering faculty who desired more relevant humanities and social science courses for their students. In this context, engineering education no longer presented an alternative but comparable form of liberal education; it became part of a concept of liberal education for everyone. At the same time, enrollment in profession-oriented degree programs outpaced that in liberal arts programs. Not only was the meaning of liberal education challenged to reflect the role of technology in society, it also had to accommodate the increasingly vocational orientation of the students. Facing this reality, the educational community began a search for the common ground between liberal education objectives and the objectives of baccalaureate professional degree programs.

The New Liberal Arts

The Sloan Foundation responded to a perceived crisis on the technological literacy of graduates from liberal arts colleges by embarking on an ambitious program to redefine the liberal arts for a technological society.

> If it is the goal of a liberal education to provide an acquaintance with the culture in which it is embedded, then the nature of liberal education must evolve as the culture itself evolves. Within a single society at a moment of time a satisfactory definition of liberal education can perhaps be put forward, but that definition becomes less and less satisfying as one moves from one society to another, and less and less relevant within its own society as the years pass (White, 1981, pp. 1-2).

Stephen White at Sloan called for inclusion of analytical and technological skills in a program called the New Liberal Arts. He argued that the computer age brought with it a new mode of thought, the "ability to cast one's thoughts in a form that makes possible mathematical manipulation," and the ability to perform such manipulations and conceive of their results (White, 1981, p. 6). Technology, and in particular the computer, had not only "altered the world in which the student will live," it had also changed "the manner in which he will think about the world" (White, 1981, p. 5). As a new mode of thought, technology and its application rose to the level of a liberal art.

Elting Morison of MIT responded enthusiastically to White's proposal, but warned that the objectives behind technology-oriented studies in the New Liberal Arts faced "formidable obstacles" in the fragmented undergraduate curriculum. Morison agreed that technology would constitute a new mode of thought, and in addition it could also bring coherence to undergraduate education by providing a "compelling organizing principle for bringing together all the divisions of learning" (Morison, 1981, pp. 14-15).

> These novel situations created by technology are a determining characteristic of the society college students will soon enter. It follows, I think, that students in their college years should be exposed to these situations, and given practice in dealing with them. Put simply, they should learn what it takes to develop new, sustainable, civilizing contexts for the organization of the machinery and acquire confidence in their ability to make such contexts. (Morison, 1981, p. 16)

For Morison, a "truly modern liberal education" would engage students' imaginations in reviewing the timeless concerns often associated with the humanities: "the relation between thinking and doing, the boundaries of appropriate scale, the proper claims of aesthetics and the difficulty of choice among both practical and moral considerations" (Morison, 1981, p. 16). The liberal educational task, according to the proponents of the New Liberal Arts, was to educate the "technological humanist."

Samuel Florman, an engineer who wrote eloquently about the value of liberal education for engineers, challenged the assumption that such an education would raise the social consciousness of the practicing engineer. He cautioned that "the linkage of a liberal arts education to social conscience and political awareness [was] not as direct as one might think," and that "the tastes, prejudices, and moral beliefs of individual engineers [were] not the decisive factors in the shaping of technology." He argued instead for the benefits of a liberal education to the engineer as an individual, "that a humanistic education helps engineers to appreciate the satisfactions inherent in their *own* professional work" (Florman, 1987, p. 184). He shared the opinion of White and others that non-engineers would benefit from a higher level of technological education; but for Florman, the benefit would be personal, enabling the individual to derive an "existential" pleasure from the technological world.

> It will be claimed that the ancients were able to take delight in their fabricated objects because they were not baffled by them. The work of the carpenter, the weaver, and the smith can readily be seen and understood. There is little mystery in the technology of chariots and armor. The obvious answer to this is that people today would get more pleasure out of the world if they understood more about science and technology. A good education should include enough in these areas so that the ordinary citizen is not deprived of his birthright, which includes savoring the engineering creations of his world (Florman, 1976, p. 114).

In his essay on the New Liberal Arts, White identified another formidable obstacle when he added that "remodeling a curriculum inescapably implies remodeling a faculty" (White, 1981, p. 3). By the 1980s, the tension between engineering and liberal arts faculties arose less from differences in philosophy for the general education program than from an attitude of indifference towards what general education had to contribute to the education of an engineer. Engineering professors confused their students by requiring them to take courses in the humanities and social sciences, but seldom mentioning concepts emanating from these courses in their own engineering courses (Lynn, 1977). Even worse, some engineering professors found the humanities and social sciences to be a "trivial and unnecessary part of the engineering program," passing their attitudes on to the students they advised (Goulter, 1985, p. 216). As diagnosed by an engineer writing in Liberal Education in 1977, specialization in the disciplines and the professional aspirations of both groups of faculty created an even wider gap between them:

> By and large the major failing lies, not with inept students, but with engineering faculties who have become so expert in aspects of their fields that they have lost sight of the principal roles that engineers play in society. For more than twenty-five years engineering has become more scientific, more concerned with and adept at analysis and woefully weak in dealing with issues concerned with values. The faculty who are better at analysis also seek to train their students in their own image. . .
>
> We need to learn about values and how to call to our student's attention the value issues that pervade most of engineering works. We also will need the assistance of our colleagues in the humanities and social sciences who are willing to come to grips with value issues in relatively specific contexts. Needless to say, such cooperative ventures are not easy to achieve since faculty in the humanities and

> social sciences are as much preoccupied with specialization as are those of us in the sciences and engineering (Lynn, 1977, pp. 254-257).

"[L]ong-standing prejudices and academic politics," according to Florman, also contributed to the gap between the engineers and the humanists:

> There is little satisfaction, reputation, or advance toward tenure associated with teaching literature or history to engineers . . . In engineering schools where a small liberal arts faculty constitutes a designated resource for the engineering students, there is likely to be more dedication to the job at hand, but this is offset by other disadvantages. The distinction of large liberal arts departments is missing. The non-engineering faculty are often viewed as second-class citizens, and their offerings are thus tainted (Florman, 1987, p. 202).

It became clear that engineering faculty would have to play a central role in integrating issues concerned with values into the content of the engineering curriculum, and they could not do it without help and participation from their colleagues in the humanities and social sciences. Under the auspices of the New Liberal Arts program at Sloan, faculty members from small, liberal arts colleges and large, state universities engaged in a variety of experiments designed to "breach the barricades of prejudice and remove the hostilities and misconceptions, for the mutual benefit of everyone, between the engineers and the humanities and social science faculty" (Slaght, 1988, p. i). These experiments and others provided the impetus for the creation of Science, Technology, and Society (STS) and similar programs for the next twenty years (for a history and analysis of STS programs see: Cheek, 1992).

The Unfinished Design of the Engineering Curriculum

Following several critical reports on the status of undergraduate education from 1979 to 1981, the Association of American Colleges (AAC) initiated the Project on Redefining the Meaning and Purpose of Baccalaureate Degrees, including input from faculty and administrators of eleven colleges and universities representing the spectrum of higher educational institutions in the U.S. The authors of the report, Integrity in the College Curriculum, echoed the concerns of the New Liberal Arts proponents, but reinforced the view that the humanities and social sciences were essential to developing contextual understanding of complex problems:

> Leaders in a complex, pluralistic society require not only technical or professional expertise but also the ability to make consequential judgments on issues involving the contextual understanding and assessment of multi-faceted problems. (AAC, 1985, p. i)

The <u>Integrity</u> report is best known for its recommendation of experiences essential to general education: inquiry, abstract logical thinking, critical analysis, literacy, understanding numerical data, historical consciousness, science, values, art, international and multicultural experiences, and study in depth. The report explored the reasons underlying the decay in the undergraduate curriculum, and blamed the faculty and their professional orientation for the proliferation of specialized courses at the expense of a rational, coherent educational program. When serving on college curriculum committees, the report's authors observed, the faculty tended to serve the interests of their home departments, seldom risking those interests to the uncertain threats of innovative approaches. The solution proposed by the AAC would require "bold administrative leaders and newly responsible professors" who would work to make the curriculum committee "the most intellectually exciting and challenging committee on campus." It would also require strategies aimed at "loosening the grip of academic departments on curricular arrangements" such as team teaching, honors programs, interdisciplinary programs, and joint appointments of faculty to divisions rather than disciplinary departments (AAC, 1985, pp. 6-10).

Following the <u>Integrity</u> report, the AAC studied the status of liberal education in undergraduate engineering education. Impetus for the study arose in part from the innovative efforts of several engineering programs and the writings of a few prominent professional engineers, including Samuel Florman, author of <u>The Civilized Engineer</u> (Florman, 1987). The study was intended to “improve the quality and coherence of the humanities and social sciences coursework of undergraduate engineering students” (Johnston, Shaman, & Zemsky, 1988). It included a survey of over 200 engineering programs on their policies on coursework in the humanities and social sciences, and a limited analysis of transcripts from students in 18 selected programs to determine the practices of students in selecting humanities and social science courses.

The results of the study were published in the report Unfinished Design: the Humanities and Social Sciences in Undergraduate Engineering Education. The report highlighted the limited opportunity in the engineering curriculum for humanities and social science (HSS) coursework, and revealed a general lack of coherence in the HSS requirements as designed in the curriculum and as taken by the students. The report profiled 13 innovative engineering programs that had exemplary designs for improving the liberal education of undergraduate engineers. The authors recommended strategies for improving curricular understanding through internal studies, improving academic advising by engaging the liberal arts faculty in advising engineering students, and finding principles of coherence between the humanities, social sciences and engineering courses in the curriculum (e.g., technology studies, environmental issues, international studies) (Johnston et al., 1988).

In the past decade, engineering leaders have continued to call for a more “holistic” curriculum structure that underscores the importance of developing a more sophisticated understanding of contextual issues when defining and solving engineering problems (Bordogna, Fromm, & Ernst, 1993). These authors echoed the recommendations of most of the studies on the status of engineering education, and emphasized the need for interdisciplinary learning to address the complex problems in the world:

> Thus, the intellectual mission of educators must include the cultivation of each student's ability to bridge the boundaries between disciplines and make the connections that produce deeper insights. The complexity and commingling of many engineering, industrial, economic, environmental, political, and social problems demand individuals with the technical skills and professional competence in the integrative approach to defining problems with care, seeking alternative solutions for them, and participating in their ultimate application (Bordogna et al., 1993, p. 4).

In addition to recommending structural changes to improve coherence in the curriculum, the authors explicitly identified an obligation of the faculty to promote learning across the disciplines.

Common Ground between Liberal Education and the Professions

One approach to improving coherence in the curriculum is to identify the desired competencies shared by all professions, and then identify those objectives they share in common with the objectives of a liberal education. Joan Stark, a professor of higher education at the University of Michigan, and her colleagues studied the objectives of several professional education programs and identified seven liberal education outcomes of professional study, one of which was contextual competence (Stark & Lowther, 1989). Stark labeled this considerable overlap in objectives the “common ground” between liberal and professional education. She believed that this common ground presented a significant opportunity for improving coherence in the curriculum (Stark, 1986, 1987, 1989; Stark & Lowther, 1989).

In the mid-1980s, more students enrolled in profession-oriented degree programs than in liberal studies programs. Not only were students more vocation-oriented, they also were more interested in personal rewards than concerned with the needs of the community or the greater society (Levine, 1980). Two national studies, one by the National Institute of Education (NIE) and the other by the Association of American Colleges (AAC), expressed concern about the narrow and specialized nature of the curricula in these programs. The AAC report held open the possibility that, with some modification and direction, the professional programs could provide a form of liberal education. It is in this context that the AAC undertook the Unfinished Design study.

Stark questioned the assumptions made about professional preparation programs (e.g., engineering, nursing or pharmacy) in the NIE and AAC reports. Her study sought to improve the level of understanding of these professional preparation programs, in particular the outcomes (competencies and attitudes) they held in common, the relative emphasis the faculty placed on these outcomes, and the issues the faculty had with respect to their educational programs. Stark's study included an extensive review of the literature from a wide range of professional fields and a survey of faculty in professional programs representing ten fields of study: architecture, business administration, education, engineering, journalism, law, library science, nursing, pharmacy, and social work (Stark & Lowther, 1986; Stark, Lowther, & Hagerty, 1986).

Based on a content analysis of over 600 articles from eleven fields of professional education, she and her colleagues identified six professional competencies and five professional attitudes (Table 1). They defined competence as "the level of proficiency that the professional program faculty expect a new entrant to the profession to demonstrate" (Stark, Lowther, & Hagerty, 1986, p. 19). Of particular interest to this study is the authors' definition of contextual competence:

> "Contextual competence" signifies an understanding of the broad social, economic, and cultural setting in which the profession is practiced (McGlothlin, 1964). It refers not only to the professional's specific work setting, but also to the larger environments, both social and natural, within which the work is embedded. The acquisition of the competence implies that the student can examine the environmental context from a variety of vantage points: historical, social, economic, psychological, political, and philosophical. The capability to adopt multiple perspectives allows the student to comprehend the complex interdependencies between the profession and society, thus fostering both

> increased professional awareness and more effective citizenship (Smith, Johnson, & Johnson, 1981; in Stark, Lowther, & Hagerty, 1986, pp. 30-31).

Implied in this definition is a broader, “more purposeful” meaning of the term “contextual.” Stark suggested that the inclusion of contextual competence as an outcome of the professional curriculum implied a direct connection between the non-professional or liberal studies to professional practice. This connection formed part of her argument that professional education could constitute a form of liberal education distinguished from that derived from distribution requirements. “Professional study with appropriate contextual requirements need not be narrow in scope, but it differs in clarity and purposive intent from so-called distribution requirements aimed at providing general breadth” (Stark, Lowther, Hagerty et al., 1986, p. 246).

Stark understood that the contribution of the liberal arts to professional education had been debated throughout the history of most of the professions, in particular with respect to the amount and nature of humanities and social science coursework. Also debated was whether such courses were the “appropriate curricular vehicle” to achieve the desired educational objectives (Hodges & Lichter, 1980; cited in Stark, Lowther, & Hagerty, 1986, p. 31). In subsequent articles on the 1985 study, Stark argued that the professional preparation programs included many of the same outcomes associated with a liberal education and that the overlap in objectives constituted a common ground between liberal education and the professions. To illustrate this point, Stark and her colleagues redefined the competencies and organized them into three categories (Stark, 1987, p. 91):

1. Traditional professional competencies: conceptual competence, technical competence, integrative competence, and career marketability
2. Short-term liberal education outcomes: communication and <u>contextual competencies</u>, professional identity and ethics; and

3. Long-range liberal education outcomes: adaptive competence, scholarly concern for improvement of the profession, and motivation for continued learning.

For Stark, curriculum development on the common ground between the liberal arts and the professions would benefit not only students in professional programs such as engineering, but undergraduate students at-large. Her argument echoed that of the *New Liberal Arts* proponents:

> Finally, as technology changes our society, both liberal arts students and students in career programs will need to be aware of technology's utility and potential to change society in basic ways. Consideration of technological change from the standpoint of professional practice as well as from the point of view of an educated citizen may provide a balanced perspective (Stark, 1987, p. 100).

The commonalities among the academic disciplines could also improve curricular coherence. Stark identified “unifying themes for progress” towards curricular coherence and recommended several strategies for achieving it. She suggested defining a common core of studies for all students, improving teaching and learning processes, increasing student involvement in learning, developing thematic linkages across disciplines, and assessing specific student outcomes (Stark, 1989, p. 65). While the concept of the common ground showed “great potential,” it remained “relatively unexplored.” At the time of the 1985 survey, a minority of the faculty in any of the professional fields reported engaging in an active debate on the liberal arts courses taken by their students (less than 30%) and even fewer were considering the difficult challenge of integrating liberal and professional studies (less than 20%). In spite of Stark’s belief in the value of developing the common ground between liberal and professional education, she cautioned there was little empirical evidence to support the claim that incorporation of liberal arts content into the professional curriculum would change faculty and student attitudes (Stark, Lowther, & Hagerty, 1986).

Differences in the Disciplines and Educational Goals of the Faculty

The common ground in the engineering curriculum may be relatively unexplored because of differences in the disciplines of engineering and the humanities and social sciences (Biglan, 1973a, 1973b; see also Creswell & Roskens, 1981, for a review of studies associated with Biglan). Biglan examined the nature of the disciplines from a psychological perspective, linking content and methods to the cognitive processes of the faculty. Biglan studied faculty at a large, state university and a small, private college and developed a typology that clustered the disciplines according to three characteristics of the subject matter: (1) hard versus soft, in terms of the degree to which the discipline is organized around a single paradigm; (2) pure versus applied, with respect to the concern of the discipline with solving practical problems; and (3) life systems versus non-life systems, indicating whether the discipline is concerned with animate or inanimate objects.

Differences in Objectives

According to Biglan’s typology, engineering as a discipline is hard, applied, and concerned primarily with inanimate objects (nonlife systems). The humanities and social sciences are soft, pure, and concerned with living systems (for example, history), or applied and concerned with living or nonliving systems (such as economics). The difference between the faculties in engineering and the humanities and social sciences could be described as a difference in the object of their work. Engineers focus on defining problems and developing solutions to them. Humanists are interested primarily in the human processes and experiences associated with particular problems, events, or outcomes. This difference in objectives or motivation for work influences the objectives faculty members define for the courses they teach and the evaluation methods they use to assess student learning.

The disciplines also differ in the way in which knowledge is structured, and these structures influence the sequencing of courses in a curriculum. Biglan (1973) described scientific knowledge as cumulative and hierarchical, and humanistic knowledge as reiterative and concentric. The structure of knowledge in the social sciences depends on the extent to which it employs the scientific method, but in general it is relational in character. The nature of engineering knowledge is reflected in the hierarchical arrangement of courses in the curriculum, a sequence that begins with mathematics and the sciences in the general education component and progresses through increasingly complex courses in the engineering component. Coursework in the humanities and social sciences can be taken in a sequence independent from scientific-technological core, the sequence having little if any perceived impact on the development of technical problem-solving skills by the students.

Social Connectedness, Shared Goals, and the Effectiveness of the Academic Program

The social interaction of faculty members within and across the disciplines is a significant factor when examining potential differences in educational objectives and goals in an academic program (Stark & Lattuca, 1997). Biglan identified the social interaction of scholars as an indicator of the "social connectedness" of a department. He defined three dimensions of social connectedness among scholars: (1) whether a scholar liked working with his colleagues, (2) the extent to which his colleagues exerted influence on him and his work, and (3) the extent to which he collaborated with his colleagues (Biglan, 1973b). The measures Biglan used to assess these variables are shown in Table 2**.** He found that social connectedness affected the functioning of the academic department, i.e., the more socially connected a department was, the more effectively it operated. Biglan found a high level of social connectedness among faculty in the hard disciplines, a result he interpreted as being related to the role of a strong paradigm in a discipline. He explained his finding on the social connectedness among faculty in hard disciplines (such as engineering) using a description of the paradigm that was quite similar to that presented by Vincenti (1990) and Staudenmaier (1985):

> Connectedness may also be more highly related to scholarly output in paradigmatic areas because the paradigm permits research problems to be efficiently broken into subproblems with confidence that the results for each part can be reintegrated (Biglan, 1973b, pp. 210-211).

Biglan’s findings reveal the importance of considering the nature of a discipline when comparing variables associated with collaborative activities, scholarly output, and the distribution of work among research, teaching, and service activities. They also present an opportunity to examine differences among faculty members in an academic *program*, versus a department, such as the faculty in engineering and the humanities and social sciences responsible for the multidisciplinary (what Stark would call “liberal”) outcomes of the engineering curriculum (e.g., contextual competence).

Vreeland and Bidwell (1966) found substantial evidence in the literature that their discipline directly influenced faculty members’ goals and objectives for an academic program, and that these goals in turn influenced the development of student values and attitudes. Their study found that faculty members in different disciplines had different educational goals and values, and that the goals differed in terms of the extent to which they emphasized technical goals, moral or social goals, or a combination of the two (mixed goals). Technical goals were those whose primary emphasis was on presenting the content of the subject matter, or on preparation for an occupation without concern for the occupation’s values or ethics. Moral goals were those whose primary emphasis was on changing attitudes about the field, developing commitment to the values and attitudes of an occupation, and on liberalizing and humanizing students.

Vreeland and Bidwell (1966) used focused interviews with 127 faculty members to develop a matrix of departmental educational goals (from technical to moral) and the departments’ social characteristics or attributes (interest and interaction with students). They found that engineering faculty had a high level of consensus on technical goals and a moderate level of interaction with students. With the exception of psychology, which also had a high level of consensus on technical goals, the faculty in the humanities and social sciences tended to exhibit higher levels of consensus on moral or social goals and a higher level of interaction with students. They argued that the discipline of an academic department, combined with the level of student interaction, would have a more significant effect on the development of values and attitudes in students than interaction with “role model” faculty members. They concluded that academic programs that have a high level of consensus among the faculty on moral or social educational goals would have a more significant effect (in terms of consistency and extent) on the development of students’ values and attitudes.

Another study examined how participation in an interdisciplinary general education program influenced the educational objectives and goals of faculty members from different disciplines. Gamson (1966) studied faculty members in the natural sciences, social sciences, and the humanities who collaborated in a special interdisciplinary program on general education at a large, state university in the 1960s. The program was intentionally “non-vocational,” focusing 40% of the curriculum on general education studies organized into small classes and taught by a devoted faculty. Gamson’s study explored the “collective beliefs and norms which emerged among the faculty members during the first four years of the college” (Gamson, 1966, p. 47). She conducted interviews with 30 of the 32 faculty members in the general education program on their educational objectives and conceptions of effects on students.

Gamson found that over time the faculty members' views regarding educational objectives "crystallized into sets of shared conceptions and norms," and that differences and conflicts tended to follow disciplinary lines. The combined faculties seldom met as a group and their main point of interaction was an interdisciplinary senior seminar. After the first year, the senior seminar became two parallel courses, one taught by faculty in the natural sciences and the other by the faculty in the humanities and social sciences. During the early years of the program, "the disparities between the departments became exacerbated by personality clashes and power struggles" (Gamson, 1966, p. 49). One point of difference was whether students should become integrated into the general college versus socialized within their major departments. The natural science faculty did not perceive a need for their students to become integrated into the general college. Gamson found that

> for the natural scientists, affecting students cognitively was enough; changes other than this were seen as undesirable or irrelevant. The social scientists share this mission but wanted to do more—to change the students' values and self-identities (Gamson, 1966, p. 72).

A later study of departmental teaching goals supports Gamson's findings. Smart found that engineering faculty "attached greater importance to the vocational development and preparation of students" than their colleagues in the humanities and social sciences, who favored "character and personal development" in their students (Smart, 1982, p. 187).

Faculty Attitudes toward Liberal Education Outcomes

The differences in the disciplines are also reflected in the attitudes of the faculty in engineering and the humanities and social sciences toward the liberal education outcomes in the curriculum. Stark and Lowther surveyed 2,230 faculty in 732 professional education programs in 346 different colleges on the importance of various competencies and attitudes in professional education and the importance that should be placed on them in the curriculum (Stark & Lowther, 1986). Of particular interest to this study are their findings related to contextual competence. With the exception of faculty in engineering, they concluded that “professional faculty in undergraduate fields strongly valued program emphasis on contextual competence” (Stark & Lowther, 1989, p. 11). They further explained the engineering faculty response: The engineering faculty reported that courses in the humanities and social sciences did not adequately address the contextual concerns of engineering. Instead of relying on courses in the humanities and social sciences, they incorporated contextual content into engineering courses, design exercises, and other practical experiences. As a result, the engineering faculty reported that the social sciences and humanities contributed little to the formal education of the engineering professional beyond the development of communication skills and other general education outcomes (Stark & Lowther, 1989).

Stark and her colleagues anticipated that contextual competence would be fostered in part through course work in the humanities and social sciences. An earlier study by Vandermeer and Lyons (1980) of professional faculty and their attitudes toward the liberal arts found that engineering faculty were dissatisfied with the humanities and social science courses taken by their students. They believed that survey courses in the humanities and social sciences did not provide “adequate depth,” and that electives competed with “attractive [technical] skill courses.” In addition, typical liberal arts courses were “too abstract and too removed” from the realities of the professional world. Vandermeer and Lyons found that engineering faculty, facing pressure to include an expanding technical base within the constraints of the four-year degree, favored “no growth or a reduction in liberal arts courses” (cited in Stark, Lowther, & Hagerty, 1986, p. 35; Vandermeer & Lyons, 1979).

Stark found evidence that, while the engineering faculty favored fewer liberal arts courses, they often incorporated liberal arts content into the professional component of the curriculum through interdisciplinary courses and technical electives. The trend at the time was for faculty “to teach contextual courses within their own programs to ensure content relevance rather than relying on liberal arts requirements or electives to provide necessary context” (Stark, 1987, p. 96). The faculty responding to her 1985 survey reported over 13,000 activities that they believed helped students achieve the outcomes associated with a liberal education (including contextual competence). Of these, only 532 involved coursework taken outside the professional program and a mere 151 addressed the development of contextual competence (Stark & Lowther, 1989). Compared to the other professions, engineering faculty reported considerably fewer activities to achieve contextual competence (Stark, Lowther, & Hagerty, 1986). In general, students in professional programs developed contextual competence through “formal professional course work, selected field experiences, and various informal activities” (Stark & Lowther, 1989, p. 14).

Stark and Lowther (1989) found that the engineering and liberal arts faculties shared responsibility for “contextual study,” but the “relatively weak coordination” among the faculties left students to “acquire contextual knowledge” through elective liberal arts courses (Stark & Lowther, 1989, p. 14). Stark believed that the development of engineering-specific liberal arts content within the engineering curriculum meant that the engineering faculty valued the contributions of the liberal arts to their programs, but “distrusted” the way traditional liberal arts courses were taught (cited in Stark, Lowther, & Hagerty, 1986, p. 33; Vandermeer & Lyons, 1979). Stark concluded, “Apparently the question of taking more courses is different from valuing the outcomes” (Stark & Lowther, 1989, p. 13).

Two other studies of faculty attitudes toward liberal and professional outcomes both support and contradict Stark's findings (Gross, 1988; Opper, 1992). In his study of faculty in applied (including engineering) and pure (arts and sciences) disciplines at the University of Florida and Florida State University, Opper (1992) asked 32 faculty members to rate Stark's professional competencies and attitudes using a Likert-type scale. For each outcome, the respondents were asked to select among four options: (1) the outcome should not be emphasized; (2) it should receive slight emphasis; (3) it should receive moderate emphasis; or (4) it should require heavy emphasis. Opper found that most of the respondents rated all ten of the outcomes as warranting "moderate or heavy emphasis." Contextual competence placed fourth overall in importance. In addition, the faculty in the applied and pure disciplines did not differ significantly in the way they ranked the outcomes. He concluded that the "pattern of the responses suggests agreement among faculty in the liberal and professional degree programs" on the importance of these outcomes (Opper, 1992, p. 146).

Gross (1988) used survey data from 629 faculty from land-grant institutions "to investigate the opinions of professional and general education faculty groups about the relative importance of specific competencies as desired outcomes of general education for professional baccalaureate students" (Gross, 1988, p. 27). She developed a broader list of 34 competencies drawn from the literature and organized them into eight groups: communication, resources and the environment, lifelong learning, reasoning and critical thinking, citizenship, values and beliefs, times and cultures, and interdependence (competencies were drawn from Boyer & Levine, 1981; Dressel, 1979; Harvard, 1945; McGrath, 1959; Pillepich, 1962). Gross analyzed the responses by professional area and faculty gender, rank, highest degree earned, and age.

Gross found that liberal arts faculty rated more of the competencies higher than engineering faculty, and that the engineers

> placed less importance than others on the fine arts, reading, values and beliefs, times and culture, and the impact of decisions on others. They placed more importance on the effects of science and technology and on the concepts of numbers and quantity than other groups. Data in this study indicated that these groups appear to hold less favor for general education skills than other groups as evidenced by the low mean values for many of the competencies (Gross, 1988, pp. 79-80).

While the study results showed general agreement with Stark (1986) on the importance engineers placed on comparable competencies (for example, the relatively low value placed on the outcomes equivalent to contextual competence compared to the technical competencies associated with science, technology and mathematics), Gross found that the engineering faculty placed a lower value overall on the general education outcomes. Finally, Gross found that the faculty responses differed significantly when “grouped by professional area and gender, but not by rank, highest degree earned, or age” (Gross, 1988, pp. 76-77).

The Common Ground Between General Education and Engineering Education

The obligations of engineering faculty with respect to the curriculum are expressed in the criteria for accrediting engineering programs promulgated by the Accreditation Board for Engineering and Technology (ABET), an organization comprising academic and practicing engineers. The ABET engineering criteria describe the requirements for degree programs in a variety of engineering disciplines (Appendix A). While the engineering criteria identify the general subject areas and competencies appropriate to each engineering discipline, they do not prescribe specific course content or instructional methods. The ABET accreditation process is performance-based. It allows the faculty to define a curriculum and educational environment suitable for achieving the desired outcomes (specified by ABET criterion 3, outcomes a-k), and in return requires a demonstration of program quality based on the results of an on-going program of performance assessment.

The educational outcomes for the engineering curriculum specified in ABET criterion 3 incorporate the cumulative experience of engineering educators with the baccalaureate engineering program, and reflect the current consensus on what an engineer should know and be able to do. The characteristics of the outcomes can be traced to the recommendations in numerous reports on the status of engineering education: the dominance of studies in the scientific-technological stem, the importance of design skills, and the relevance of contextual understanding to the application of both. Table 3 shows the relationship between the educational outcomes and the dimensions of engineering knowledge identified by Staudenmaier (1985) and Vincenti (1990). The educational outcomes associated with the humanistic-social stem of the engineering curriculum fall roughly into two categories of engineering knowledge, “values” and “technical skills.”

The engineering curriculum also includes a design experience (specified by ABET engineering criterion 4). The design experience is essentially a problem-defining and problem-solving activity, as described by Vincenti (1990), involving both high- and low-level design problems, with contextual issues related to the broader, societal context exerting a greater influence over the problem definition and conceptual development during the high-level design process. At the lower level of design, the engineer focuses on highly technical and detailed mathematical and scientific analyses. The design experience is intended to develop the student’s ability to design through analysis and synthesis of his learning in earlier coursework. The design problem is addressed in the context of engineering standards and realistic constraints related to economics, environment and sustainability, and/or ethical, social and political factors.

The engineering curriculum, like other baccalaureate degrees, builds upon a foundation of general education that includes the humanities and social sciences courses, as well as the courses in basic sciences and mathematics. Each educational institution develops a philosophy and approach to general education appropriate to its particular mission, it unique history and context. The study site has a core curriculum that meets the general education requirements for University System of Georgia and objectives for general education that reflect the desired competencies for all graduates from Georgia Tech. It is assumed that students completing the core curriculum and courses in the major would also satisfy the general education objectives for the institution. The documents describing the core curriculum requirements for Georgia Tech and the University System of Georgia can be found in Appendix B.

The general education policy implicit in the core curriculum is distributional, with credit hours distributed across six categories. The humanities and social sciences are two of these categories and the core curriculum requires students to complete 12 credit hours of social sciences and 6 credit hours of humanities. The curriculum is elective, allowing students to select courses within each category from a list of acceptable courses specified in the Georgia Tech policy. The structure of the core curriculum promotes breadth of learning across subjects, but does not require achievement of depth in either the humanities or social sciences.

The general education objectives of the Georgia Tech express the desired competencies in communication, science and mathematics, computer and information literacy, group involvement, scientific culture and values, human culture and values, and the individual and society. The general education objectives can be found in Appendix C.

Table 4 shows the relationship between the general education objectives and the engineering education outcomes required by ABET. A significant number of the outcomes of engineering education are drawn from the general education component of the curriculum, leaving only a few of the technical engineering outcomes to be addressed primarily through coursework in the engineering component of the curriculum.

The expectation that an engineering graduate would be able to define and solve problems in an ethical, contextually appropriate way is expressed in these ABET outcomes:

f) an understanding of professional and ethical responsibility
h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
j) a knowledge of contemporary issues

The parallel objectives of the general education curriculum are those related to scientific culture and values, and global awareness, human values and culture. The scientific culture and values objective states that “Georgia Tech students will demonstrate knowledge of the dynamic relationships among science, technology, cultural values, and creative expression and how these relationships must be framed by ethical principles.” The objective has two outcomes specifying that students should be able to

1. identify the interaction between science and technology and social, historical, political, and economic values.
2. identify ethical issues relating to the application of science and technology.

The global awareness, human values, and culture objective states that “Georgia Tech students will be able to articulate their personal and social values, articulate how those values have been informed by both humanistic and social perspectives, understand how these shape their view of the world, and compare these with other world values.” It has three outcomes specifying that students should be able to

1. demonstrate knowledge of the diversity of values and traditions, including the contributions of diverse groups, which shape society and institutions
2. describe the organization and operation of a social or political system that governs society.
3. relate significant historical events to their effects on contemporary society.

The competencies specified by the ABET educational outcomes and the general education outcomes at Georgia Tech are also related to the professional competencies and attitudes identified by Stark et *al.* (1986). Table 5 shows the relationships between engineering knowledge and the competencies as identified by Stark, ABET, and the general education objectives at Georgia Tech.

Relevance of the Literature to the Study

According to the studies reviewed in this chapter, contextual competence has always been an objective of engineering education. When addressing the objectives related to contextual competence, the authors of the national reports on engineering education consistently focused on the importance of studies in the humanities and social sciences to the formal education of an engineer. Throughout the history of engineering education at the collegiate level, however, collaboration among faculty members in engineering and the humanities and social sciences has been hampered not only by epistemological differences, but also by tensions of a more personal nature whose origins can be traced to the introduction of engineering's more vocation-oriented objectives into higher education in the 19th century. In the engineering curriculum, the epistemological relationships among mathematics, sciences and engineering led naturally to a relatively high level of coordination and curricular coherence. These relationships were strengthened in the mid-1950s, when engineering science and the scientific method became central features of engineering. The emergence of engineering science shifted the emphasis in the curriculum towards analysis and away from design and effectively displaced coursework in the humanities and social sciences (Seely, 1999). The result has been an increasing gap between the faculties contributing to the scientific-technological and humanistic-social stems of the engineering curriculum, and few serious efforts to improve the effectiveness of the curriculum with respect to multidisciplinary outcomes such as contextual competence. While faculty members in engineering and the humanities and social sciences share responsibility for many multidisciplinary outcomes in the baccalaureate curriculum, they seldom interact with each other sufficiently to coordinate, let alone integrate, their respective efforts (Stark & Lowther, 1989).

One objective of the protocol developed in this study is to have faculty members in engineering and the humanities and social sciences define contextual competence in the undergraduate chemical engineering curriculum. The objective is not only to develop a more specific construct of the competency, but also to determine the level of consensus on the definition among the faculty members within chemical engineering and between the faculty members in chemical engineering and the humanities and social sciences. This objective was derived from the finding that the effectiveness of an academic program is related to the level of consensus among the faculty members on educational objectives. This aspect of the protocol builds on the work of Vreeland and Bidwell on the goal orientations of faculty in the disciplines, the Sloan Foundation on liberal arts for the technological humanist, Stark and her colleagues on the common ground between liberal and professional education, the AAC on the Unfinished Design of the engineering curriculum, and Besterfield-Sacre and her colleagues on the lack of construct specificity for the engineering outcomes (Besterfield-Sacre, Shuman et al., 2000; Johnston et al., 1988; Stark, 1986, 1987, 1989; Stark & Lowther, 1989; Vreeland & Bidwell, 1966; White, 1981).

A second objective of the protocol is to capture faculty opinions on the contribution of coursework in engineering and/or in the humanities and social sciences to the development of contextual competence. This objective is also related to the relationship between faculty consensus on educational objectives and the effectiveness of an academic program. The objective is to ascertain whether CHE and HSS faculty members have a consensus of opinion favoring coursework in engineering or the humanities and social sciences for the development of contextual competence. This aspect of the protocol builds on the findings of Stark and her colleagues, Opper, and Gross on engineering faculty attitudes toward the liberal education outcomes of the curriculum. Most of these studies found that engineering faculty valued the liberal education outcomes of the engineering curriculum such as contextual competence. Stark's study found, however, that engineering faculty did not value the contribution of coursework in the humanities and social sciences to the development of these outcomes (Gross, 1988; Opper, 1992; Stark & Lowther, 1986; Stark et al., 1988; Stark, Lowther, & Hagerty, 1986, 1987; Stark, Lowther, Hagerty et al., 1986).

A third objective of the protocol is to characterize the social connectedness of the faculty members in engineering and the humanities and social sciences. Social connectedness was identified as an important influence on the ability of faculty in an academic program to develop a set of shared objectives for multidisciplinary outcomes in the engineering curriculum. This aspect of the protocol builds on the work of Biglan, who found that the social connectedness of an academic department influences its effectiveness in achieving desired objectives (Biglan, 1973b). Biglan defined social connectedness in terms of the individuals in the academic program who influenced the faculty members' work, the amount of collaboration among the faculty members in the academic program, and the number of individuals in the academic program identified by the faculty as people with whom they like to work. This objective of the protocol also draws from the experience of Gamson in her study of faculty in an interdisciplinary general education program. Gamson found that over time faculty attitudes coalesced along disciplinary lines, a result she attributed to the minimal level of interaction among faculty members across the disciplines (Gamson, 1966).

Table 1. Professional Preparation Outcomes

Professional Competencies	Short Definition	Professional Attitudes	Short Definition
Conceptual competence	Understanding the theoretical foundations of the profession	Career marketability	The degree to which a graduate becomes marketable as a result of acquired training
Technical competence	Ability to perform tasks required of the professional	Professional identity	The degree to which a graduate internalizes the norms of the profession
Contextual competence	Understanding the societal context (environment) in which the profession is practiced	Ethical standards	The degree to which a graduate internalizes the ethics of the profession
Interpersonal communication competence	Ability to use written and oral communication effectively	Scholarly concern for improvement	The degree to which a graduate recognizes the need to increase knowledge in the profession through research
Integrative competence	Ability to meld theory and technical skills in actual practice	Motivation for continued learning	The degree to which a graduate desires to continue to update knowledge and skills
Adaptive competence	Ability to anticipate and accommodate changes (for example, technological changes) important to the profession		

Note. Adapted from the operational definitions provided in the appendix of "Conceptual Framework for the Study of Preservice Professional Programs in Colleges and Universities," by J.S. Stark, M. A. Lowther, B. Hagerty, and C. Orczyk, 1986, Journal of Higher Education, 57, pp.252-253.

Table 2. Operational Measurement of Social Connectedness and Commitment

Variables	Description
Social Connectedness	
Number of others—like to work with	Respondents to the questionnaire listed people they said they like to work with on teaching, research, and administration. The number of people named for each of the tasks was a measure.
Number of sources of influence	Respondents were asked to indicate the individuals and groups who influenced their research goals and teaching procedures. The number of sources indicated was the measure.
Collaboration	Respondents to the questionnaires indicated the number of fellow faculty members with whom they worked directly on research and teaching. A second measure of research collaboration was obtained by tabulating the number of coauthorships each faculty member had on his journal articles.
Commitment	
Preferences	Questionnaire respondents were asked to distribute 100 points among the following tasks in accordance with their preferences for each task: teaching, research, department administration, university administration, and service.
Time allocation	In a similar manner, respondents distributed 100 points among these tasks to indicate the proportion of time they spent on each. Since respondents also indicated the number of hours they spent on all university work, it was possible to devise measures of time spent on each activity.

Note. From Table 1 “Operational Measurement of Social Connectedness and Commitment Variables” in “Relationships between Subject Matter Characteristics and the Structure and Output of University Departments,” by A. Biglan, 1973, Journal of Applied Psychology, 57(3), p. 206.

Table 3. Relationship between ABET Criterion 3 Educational Outcomes and Engineering Knowledge

Engineering Knowledge Based on Vincenti and Staudenmaier	ABET Engineering Criteria 2000 Criterion 3: Program Outcomes (3a-k)
1. Scientific concepts	3a) An ability to apply knowledge of mathematics, science, and engineering.
	3b) An ability to design and conduct experiments, as well as analyze and interpret data.
2. Problematic data	3b) An ability to design and conduct experiments, as well as analyze and interpret data.
3. Engineering theory	3c) An ability to design a system, component, or process to meet desired needs.
	3k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
4. Technical skills	3d) An ability to function on multidisciplinary teams.
	3e) An ability to identify, formulate, and solve engineering problems.
	3g) An ability to communicate effectively.
5. Values	3f) An understanding of professional and ethical responsibility.
	3h) The broad education necessary to understand the impact of engineering solutions in a global and societal context.
	3i) A recognition of the need for, and an ability to engage in life-long learning.
	3j) A knowledge of contemporary issues.

Note. Developed by the researcher from What Engineers Know and How They Know It: Analytical Studies from Aeronautical History, by W. Vincenti, 1990, Baltimore: Johns Hopkins University Press; Technology's Storytellers: Reweaving the Human Fabric, by J. Staudenmeier, 1985, Cambridge: The MIT Press; and Criteria for Accrediting Engineering Programs: Effective for Evaluations During the 2003-2004 Accreditation Cycle, 2003, Baltimore: Accreditation Board for Engineering and Technology.

Table 4. Comparison of Georgia Tech General Education Objectives with the ABET Outcomes of Engineering Education

General Education Objectives at Georgia Tech	ABET Engineering Criteria Criterion 3: Program Outcomes (3a-k)
1. Communication	3g) An ability to communicate effectively
2. Science and mathematics	3a) An ability to apply knowledge of mathematics, science, and engineering. 3b) An ability to design and conduct experiments, as well as analyze and interpret data.
3. Computer and information literacy	3k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
4. Group involvement	3d) An ability to function on multidisciplinary teams. 3g) An ability to communicate effectively.
5. Scientific culture and values	3f) An understanding of professional and ethical responsibility. 3h) The broad education necessary to understand the impact of engineering solutions in a global and societal context.
6. Global awareness, human culture and values	3h) The broad education necessary to understand the impact of engineering solutions in a global and societal context. 3j) A knowledge of contemporary issues.
7. Individual and society	3i) A recognition of the need for, and an ability to engage in life-long learning. 3j) A knowledge of contemporary issues.
Engineering-specific outcomes	3c) An ability to design a system, component, or process to meet desired needs. 3e) An ability to identify, formulate, and solve engineering problems. 3k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. Criterion 4: A design experience integrating earlier coursework and incorporating engineering standards and realistic constraints.

Note. Adapted from an internal report developed in 1999 by the J. Hoey, Director, Office of Assessment, Georgia Institute of Technology.

Table 5. Relationship between Engineering Knowledge and Competencies for the Professions, for Engineers, and for All Graduates of Georgia Tech

Engineering Knowledge	Professional Competencies and Attitudes by Stark et *al.* (1986)		ABET Engineering Criteria Criterion 3: Program Outcomes (3a-k)		General Education Objectives at Georgia Tech
1. Scientific concepts	Conceptual competence	Understanding the theoretical foundations of the profession.	3a)	An ability to apply knowledge of mathematics, science, and engineering.	Science and mathematics
			3b)	An ability to design and conduct experiments, as well as analyze and interpret data.	
2. Problematic data	Adaptive competence	Ability to anticipate and adapt to changes (e.g., technological changes) important to the profession.	3b)	An ability to design and conduct experiments, as well as analyze and interpret data.	
3. Engineering theory	Integrative competence	Ability to integrate theory and practices.	3c)	An ability to design a system, component, or process to meet desired needs.	Computer and information literacy
			3k)	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	
4. Technical skills	Technical competence	Ability to perform tasks required of the professional.	3d)	An ability to function on multidisciplinary teams.	Group involvement
			3e)	An ability to identify, formulate, and solve engineering problems.	
	Interpersonal communications	Ability to use written and oral communication effectively	3g)	An ability to communicate effectively.	Communication

Engineering Knowledge	Professional Competencies and Attitudes by Stark et *al.* (1986)		ABET Engineering Criteria Criterion 3: Program Outcomes (3a-k)		General Education Objectives at Georgia Tech
5. Values	Professional identity	The degree to which a graduate accepts the norms of a profession.	3f)	An understanding of professional and ethical responsibility.	***Scientific culture and values***
	Professional ethics	The degree to which a graduate internalizes the ethics of a particular profession.			
	Contextual competence	***Understanding of the societal context (environment) in which the profession is practiced.***	***3h)***	***The broad education necessary to understand the impact of engineering solutions in a global and societal context.***	***Global awareness, human culture and values***
			3j)	A knowledge of contemporary issues.	
	Career marketability	The degree to which a graduate becomes marketable due to acquired training.	3i)	A recognition of the need for, and an ability to engage in life-long learning.	Individual culture and values
	Scholarly concern for improvement	The degree to which a graduate recognizes the need to increase knowledge through research.			
	Motivation for continued learning	The degree to which a graduate desire to continue to update knowledge and skills.			

CHAPTER 3

RESEARCH METHODOLOGY

This strategy of inquiry for the study is a case study as defined by Yin (1994). The case study design focuses on a single, embedded case of faculty in an academic department in engineering and the complement of humanities and social sciences faculty responsible for teaching the general education courses in the curriculum. The case study involves the development and implementation of a two-questionnaire protocol as the main method for data collection. The case study is intended to serve as an instrumental or revelatory case, providing insight into how faculty members defined the concept of contextual competence, how they thought courses in the curriculum contributed to the development of it, and how they would evaluate the contextual competency of engineering students. The case study is also intended to provide insight into whether participation in the protocol would influence how engineering faculty defined the concept of contextual competence. The two questionnaires are designed to address the research questions in this study:

1. How do faculty members in engineering and in the humanities and social sciences define contextual competence?
2. In which courses in the undergraduate curriculum do faculty members in engineering and in the humanities and social sciences believe contextual competence is best developed?
3. Do faculty in engineering and in the humanities and social sciences believe that adequate emphasis is placed on contextual competence in courses in engineering courses or in courses in the humanities and social sciences?

4. How would faculty members in engineering and in the humanities and social sciences evaluate student achievement of contextual competence? When and where (e.g., in what courses) in the academic program would they evaluate student achievement?
5. What effect does participation in the protocol have on how engineering faculty define contextual competence? Does the protocol provide useful information for faculty members interested in academic program improvement?

This chapter begins with a description of the procedures for selecting the case study site, the academic program, and faculty participants. It continues with the procedures for developing and testing the two questionnaire instruments followed by the procedures for implementing them during the data collection phase of the study. The chapter concludes with a description of the procedures for analyzing the data and verifying the trustworthiness, authenticity, dependability, and transferability of the study results.

Selection of the Case

The selection of the case study site was purposive, reflecting a goal to select a site that would be viewed as relevant by administrators and faculty interested in academic program improvement and located in institutions responsible for conferring a large proportion of bachelor’s degrees in engineering in the United States. The relevance of the case study site was determined by the size of the engineering program as defined by the number of bachelor’s degrees conferred annually; the emphasis on research and teaching as indicated by the highest degree conferred in engineering, the doctorate; and the quality of the engineering program as defined by the program’s national ranking (U.S. News & World Report, 2004). There are 350 institutions in the U.S. offering accredited engineering programs. When ranked by the number of bachelor’s degrees conferred in engineering, the top 25 institutions accounted for 31% of all bachelor’s degrees conferred in 2003. All of these institutions were doctoral level institutions (ASEE, 2004). When ranked by quality, the top 25 institutions accounted for 24% of all bachelor’s degrees in engineering conferred in 2003 (ASEE, 2004; U.S. News & World Report, 2004).

At least one-fourth of the bachelor’s degrees in engineering are awarded annually by 7% of the institutions offering engineering degrees. The top 25 programs, defined in terms of size or perceived quality, play a significant role nationally not only as educators of engineers, but also as influential peers to faculty and administrators in other institutions who aspire to be among them. The selection of a case study site that provided insight into one of these top engineering programs would meet the goal of the study to be of interest to faculty and administrators at many other institutions.

A second goal of the site selection process was to identify a site where one would likely find dissimilar, more discipline-oriented perspectives on multidisciplinary outcomes between the faculties in engineering and in the humanities and social sciences. The institutional policy on general education was identified as a factor that would influence the extent of integration across courses in general education and the major and, specifically, the level of interaction among faculty members in engineering and in the humanities and social sciences. Vars (1982) observed that students in academic programs with general education based on distribution requirements (credit hour requirements distributed across several subject categories) would receive limited assistance with integrating learning across courses and very little exposure to models of integrated or interdisciplinary scholarship by the faculty (Vars, 1982). With respect to the general education component of the engineering curriculum, and in particular the humanities and social sciences, another study identified the institutional policy on general education as one factor affecting the ability of engineering students to achieve the type of integration implicit in some of the multidisciplinary outcomes in the undergraduate engineering curriculum (Johnston et al., 1988). In the site selection process, it was assumed that faculty in academic programs based on a distributional form of general education would present more discipline-oriented perspectives on a multidisciplinary outcome than faculty in programs with a higher level of integration across courses in general education and the major.

The Case Study Site

The Georgia Institute of Technology, a public research university located in Atlanta, Georgia, was selected for the case study. The mission of the institution is "to provide the state of Georgia with the scientific and technological knowledge base, innovation, and workforce it needs to shape a prosperous and sustainable future and quality of life for its citizens" (Georgia Institute of Technology, 2004). In the year preceding the study, Georgia Tech had an enrollment of 16,643 undergraduate and graduate students and employed 801 full-time tenured faculty members. The College of Engineering is central to the overall mission of Georgia Tech, with 6,545 undergraduate students and 362 full-time tenured faculty members (Georgia Institute of Technology, 2004). In 2003, Georgia Tech awarded 1,287 bachelor's degrees in engineering, ranking second nationally and accounting for 2% of all bachelor's degrees awarded in the U.S. that year (ASEE, 2004). Georgia Tech was ranked by engineering deans and senior faculty in America's Best Colleges Guide Book as sixth in the nation among undergraduate engineering programs whose highest degree was the doctorate (U.S. News & World Report, 2004).

As stated in Chapter 2, all undergraduate degree programs at Georgia Tech build upon a common core curriculum that meets the requirements of the University System of Georgia and Georgia Tech (Appendix B). The core curriculum is based on distribution requirements, requiring students to complete 12 credit hours of social sciences and 6 credit hours of humanities. The curriculum is elective, allowing students to select courses within each category from a list of acceptable courses specified in the Georgia Tech policy. The structure of the core curriculum promotes breadth of learning across subjects, but does not require achievement of depth in either the humanities or social sciences.

The academic program selected for the case study was the Bachelor of Science degree in chemical engineering offered by the School of Chemical and Biomolecular Engineering, one of nine engineering schools in the College of Engineering at Georgia Tech. Over 400 undergraduate students enrolled in the chemical engineering program in 2003, instructed by many of the School’s 30 full-time faculty members. The School is one of 158 chemical engineering programs accredited by ABET in the United States. In 2003, these institutions conferred 5,238 bachelor’s degrees, of which the School of Chemical and Biomolecular Engineering conferred 110. The School ranked second nationally in the number of bachelor’s degrees awarded and 12th in the perceived quality among undergraduate engineering programs whose highest degree was the doctorate (ASEE, 2004; U.S. News & World Report, 2004)**.**

The chemical engineering program was selected because of its relatively uncomplicated curriculum compared to other engineering curricula at Georgia Tech. The level of complexity in the curriculum was determined by the ability of students to vary the degree program through election into areas of specialization. The chemical engineering curriculum has a core of 12 required courses and does not offer formal areas of specialization. The civil engineering curriculum, for example, is more complex, allowing students to group 12 hours of technical electives in civil engineering with six hours of approved electives into specializations such as environmental, geotechnical, infrastructure, or structural engineering. The undergraduate chemical engineering curriculum, arrayed in the recommended sequence, is displayed in Table 6.

Selection of the Case Study Faculty

The embedded case study design allows for exploration of patterns in the responses of faculty in the subunits of the academic program (Yin, 1993, pp. 21-22). The smallest subunits defined for this study are individual faculty members responsible for teaching the required courses in the chemical engineering curriculum. Other units of analysis are the respondents grouped by discipline into two faculty groups, the chemical engineering faculty (CHE faculty) and the humanities and social sciences faculty (HSS faculty). The goals of the faculty selection process were (1) to select faculty members actively involved in teaching the 12 required chemical engineering courses in the undergraduate curriculum in the School of Chemical and Biomolecular Engineering; and (2) to select faculty members in the liberal arts college of Georgia Tech (the Ivan Allen College) with experience teaching the humanities and social science courses taken by undergraduate students majoring in chemical engineering. The HSS faculty members selected for this study were not intended to be representative of all faculty members in the Ivan Allen College; they were intended instead to reflect a range of humanities and social science perspectives on contextual competence in the undergraduate engineering curriculum.

Three types of data were used in the faculty selection process: background data on the CHE faculty obtained from an ABET self-study report prepared by the faculty in the School of Chemical and Biomolecular Engineering, transcript data from a cohort of students who graduated with a bachelor’s degree in chemical engineering in May 2003, and faculty teaching data from the Georgia Tech Student Government Association Course Critique database. The

Course Critique database contains information on each section of a course taught since the year 2000 and includes data on the academic terms in which sections of a course were taught, the number of students enrolled in each section, student grades and the evaluation of the instructor by the students. The database can be queried by course number or by the name of the faculty member.

Chemical engineering faculty. Twenty-six members of the CHE faculty were actively involved in teaching the required undergraduate chemical engineering courses between the years 2000 and 2004. The sample group included current full-time faculty members and excluded those who had retired or otherwise left the School at the time of the study. The sample group was reduced to 24 faculty members through the exclusion of one senior member who participated in a pilot test of a questionnaire instrument for the study and another member who had relatively little experience teaching the undergraduate courses of interest. The final list of CHE faculty participants was reviewed and approved by the associate chair for undergraduate studies in the School of Chemical and Biomolecular Engineering.

Twenty CHE faculty members agreed to participate in the study and responded to Questionnaire 1 (83% response rate), and 17 of those 20 completed Questionnaire 2 (85% response rate). Table 7 shows that the group of respondents in the study was representative of the CHE faculty sample in terms of the type of institution attended for baccalaureate and doctoral degrees, faculty rank, experience in industry or government, registration as a professional engineer, and the year in which the doctoral degree was awarded (Georgia Institute of Technology, 2002b). Data on teaching responsibilities for the faculty between the years 2000 and 2004 were obtained from the Course Critique database. Table 8 shows that the CHE respondents to Questionnaire 1 taught a significant proportion of the 12 required chemical engineering courses in the undergraduate curriculum, accounting for more than half of the sections offered between the years 2000 and 2004 (Course Critique Committee, 2004).

Humanities and social sciences faculty. The selection process for HSS faculty included a transcript study, the identification of faculty participants by the dean of the college, and a review of the Course Critique database to verify the teaching experience of the respondents. The goal was to identify a total of 24 HSS faculty members, distributed across the subjects in numbers roughly proportional to the enrollment levels of chemical engineering students in each subject. The results of the transcript data analysis were used to identify those subjects and specific courses taken most often by chemical engineering students, the proportion of course enrollments in each subject, and the appropriate number of faculty members in the college with experience teaching each subject.

The dean of the Ivan Allen College requested transcript data for a cohort of chemical engineering students from the director of Institutional Research and Planning. The cohort was defined as those students who entered the Georgia Institute of Technology as freshmen (with fewer than 30 transfer hours) and graduated in May 2003. Of the 45 chemical engineering students graduating in May 2003, thirty-one qualified as entering freshmen. Course data files were obtained in Microsoft Excel^{TM} format for the 31 students in the transcript study cohort. Each student file was comprised of course records organized chronologically by the year in which the courses were taken. Each course record included a student identifier assigned by the researcher and fields identifying the subject, course number, course title, type of grade (letter grade, audit, pass/fail, or transfer), final grade, and term taken. The data were sorted to eliminate records for courses taken on a transfer basis and courses in which the students received grades F (fail) or W (withdrawn).

The transcript data were sorted by student identifier and the enrollment frequencies were summed across all courses in the humanities and social sciences taken by each student in the cohort. The students in the cohort enrolled 242 times in courses in the humanities and social sciences combined, with 153 course enrollments in the social sciences and 89 course enrollments in the humanities. Table 9 shows that the average number of courses taken by each student satisfied the humanities and social sciences requirements of the general education curriculum.

Enrollment frequencies for each course in the humanities and social sciences were used to identify those courses taken most often by the chemical engineering students in the cohort. Enrollment in economics was the highest since one course in this subject, Economics and Policy, is a required social science course in the chemical engineering curriculum. The other social science courses taken most often by the students in the cohort were history (History of the United States), international affairs, political science and public policy (American Government), and psychology (General Psychology). The course taking patterns of the students in the humanities were broadly distributed over several courses in literature, communication and culture, modern languages, philosophy of science and technology and courses offered by the College of Architecture. Students enrolled in 11 courses offered by the College of Architecture, six of which were history courses such as the History of Modern Industrial Design.

The relative proportion of enrollments in each subject guided the decision on the number of faculty in each subject to be solicited for participation in the study. The enrollment frequencies were reported for each subject as a percentage of all enrollments in the humanities and social sciences combined, and as a percentage of the enrollments in the humanities or social sciences, as appropriate. Table 10 shows the distribution of course enrollments for the cohort in each subject as a percentage of all course enrollments, and as a percentage of enrollments in the humanities and social science areas respectively.

Table 11 shows the distribution by subject area of HSS faculty members selected for participation in the study and the number of faculty who responded to Questionnaire 1 (58% response rate). Data from the Course Critique database were used to verify the teaching experience of the HSS respondents in the study in the humanities and social science courses taken most often by the graduating cohort of chemical engineering students, and/or their experience teaching the other humanities and social science courses taken by the students. Table 12 shows that a significant percentage of HSS faculty who participated in the study had experience teaching the courses taken most often by the chemical engineering students (71% of the HSS respondents) or experience teaching the other courses taken by the students (57% of the respondents).

Instrumentation

The case study data were collected using a two-questionnaire protocol. The questionnaire instruments were developed by the researcher for this study and implemented sequentially. Two versions of Questionnaire 1, adapted for each faculty group, were distributed to the CHE and HSS faculty members selected to participate in the study. Questionnaire 2 was developed using data obtained from Questionnaire 1, and was distributed to the CHE faculty only. Appendix D contains all of the data collection documents, including Questionnaires 1 and 2, the sample verb sheet for Questionnaire 1, the review form for Questionnaire 1, the letters of invitation from the school chair and dean for Questionnaire 1, the reminder message sent by email from the researcher to the faculty, instructions for Questionnaire 1, the consent form, and the cover letter from the researcher to the faculty for Questionnaire 2.

Questionnaire 1

Questionnaire 1 included three open-ended and six closed-form items. Two items were designed to collect additional information on the social connectedness of the faculty defined in terms of their involvement of faculty in discussions regarding contextual competence and the undergraduate curriculum, and the individuals they would contact for additional information on contextual competence (items 8 and 9 respectively). The remaining questionnaire items correspond to each of the research questions as follows:

Research Question 1: How do faculty members in engineering and in the humanities and social sciences define contextual competence?

- Item 1: Please provide a more detailed definition of this outcome [contextual competence] that you think is appropriate for graduates of the undergraduate chemical engineering program (open-ended question).
- The responses to this question were used to characterize the definitions of contextual competence provided by respondents in the two faculty groups (CHE and HSS). The definitions were characterized in terms of the number and type of outcome attributes identified by the respondents, on an individual basis and as a faculty group.

Research Question 2: In which courses in the undergraduate curriculum do faculty members in engineering and in the humanities and social sciences believe contextual competence is best developed?

- Item 4: Select the response which best describes your opinion of how students would best develop contextual competence in the courses in the undergraduate curriculum (multiple choice).

- Item 7 (to CHE faculty): It is possible that contextual competence is addressed, directly or indirectly, throughout the courses in the undergraduate chemical engineering curriculum. Based on your understanding of the courses in the undergraduate CHE curriculum, use the following scale to describe the extent to which the development of contextual competence is emphasized in each course. Please provide your best response for each course, even for those courses you do not teach (rating scale).
- Item 7 (to HSS faculty): Contextual competence may be addressed, directly or indirectly, in the humanities and social science courses taken by chemical engineering students when fulfilling the general education requirements of the Institute or the elective requirements of the chemical engineering degree program. This question is intended to identify courses that would best contribute to the development of contextual competence in engineering students. Please list those courses offered by your school/discipline that would best promote the development of contextual competence, as you defined it in question #1. Indicate the extent to which the development of contextual competence is emphasized in each course. Please provide your best response for each course, even for those courses you do not teach (open-ended for course identification, then rating scale).

Research Question 3: Do faculty in engineering and in the humanities and social sciences believe that adequate emphasis is placed on contextual competence in courses in engineering courses or in courses in the humanities and social sciences?

- Item 5a: Please select the response which best describes your opinion of the overall level of emphasis on the development of contextual competence in the required undergraduate chemical engineering courses (multiple choice).

- Item 5b: In your opinion, the overall level of emphasis on the development of contextual competence in the required undergraduate chemical engineering courses should be less, the same, or more than it currently is (multiple choice, including "no opinion").
- Item 6a: Please select the response which best describes your opinion of the overall level of emphasis on the development of contextual competence in the courses in the humanities and social sciences taken by engineering students (multiple choice).
- Item 6b: In your opinion, the overall level of emphasis on the development of contextual competence in the courses in the humanities and social sciences taken by engineering students should be less, the same, or more than it currently is (multiple choice, including "no opinion").

<u>Research Question 4:</u> How would faculty members in engineering and in the humanities and social sciences evaluate student achievement of contextual competence? When and where (e.g., in what courses) in the academic program would they evaluate student achievement?

- Item 2: How would you evaluate a student's "contextual competency"? For example, what types of evidence would a student provide in order to demonstrate his or her level of competency? (open-ended question)
- Item 3: When and where (e.g., in what courses) in the academic program could such evidence be collected? (open ended question)

<u>Research Question 5:</u> What effect does participation in the protocol have on how engineering faculty define contextual competence? Does the protocol provide useful information for faculty members interested in academic program improvement?

- The responses of the CHE faculty to Questionnaires 1 and 2 were used to characterize the definition of contextual competence on an individual basis and as a faculty group.

Differences in these data were used to assess the influence of the protocol on the CHE faculty definition of contextual competence.

The two versions of Questionnaire 1 distributed to the CHE and HSS participants differed in three ways: (1) the instructions were modified slightly to address each faculty group specifically; (2) item 7, on the emphasis on contextual competence in courses, asked the CHE faculty to rate the 12 required chemical engineering courses, and asked the HSS faculty to identify and rate courses in their respective departments that would best promote the development of contextual competence in engineering students; and (3) item 8, on curricular activities, included a sub-item for the HSS faculty related to discussions with engineering faculty about the socio-humanistic objectives of engineering courses, and included 2 sub-items for the engineering faculty related to participation on ABET review or self study committees. The two checklist questions in item 8 were adapted from another study on faculty perceptions of general education (Sellers, 1989).

The questionnaire package included additional information for the faculty to use in responding to item 1, an open-ended question on the definition of contextual competence. The additional information was a one-page verb sheet, adapted from Besterfield-Sacre (2000), that contained sample verbs for defining educational outcomes based on Bloom’s taxonomy for intellectual development (Besterfield-Sacre, Shuman et al., 2000). A copy of the verb sheet can be found in Appendix D.

Pilot Test, Questionnaire 1. Questionnaire 1, in draft form, was completed and reviewed by ten individuals at Georgia Tech known by the researcher who had expertise in engineering education, ABET accreditation, general education, or research design. The goals of the review were to assess the validity of the questionnaire items in relation to the research questions, verify the interpretability of the items by potential participants, and assess the time required for completion. The review group included eight engineering faculty members: Two had experience as ABET program reviewers, one was editor of a journal on engineering education, one had served on the Georgia Tech ad-hoc general education committee, one represented the School of Chemical and Biomolecular Engineering, and three represented other engineering disciplines. The remaining two reviewers were a researcher from the Office of Institutional Research and Planning, and an academic administrator (and HSS faculty member) responsible for oversight of the undergraduate degree programs at Georgia Tech.

Most of the reviewers agreed that the language of each question was clear, direct, and specific. The reviewers recommended instructing the faculty to read the entire questionnaire before beginning to respond. This recommendation was intended to improve response rates from respondents who may have been overwhelmed by the time required to complete the three open-ended questions on the first page. A second reviewer recommended that respondents be given the option to compose responses to the open-ended items 1, 2, and 3 using word-processing software. Several reviewers expressed concern about their limited knowledge of curricular elements outside their respective academic programs and their ability to respond to items 5 and 6 on the level of emphasis on contextual competence in courses in either chemical engineering or in the humanities and social sciences. To address these concerns, the reviewers recommended adding another response category to items 5b and 6b for respondents who did not know enough about the level of emphasis on contextual competence in the courses in the curriculum (“no opinion”). Other recommendations included minor editorial changes to improve the clarity or specificity of a questionnaire item or response category. All reviewers found the sample verb list helpful, and the average time required for completion of the questionnaire was 30 minutes. The final revised version of Questionnaire 1 was distributed to the dean of the Ivan Allen College, the chairs of the academic programs in humanities and social sciences in that college, and to the director of the Georgia Tech Office of Assessment for review prior to distribution to the participants. No additional recommendations were received for changes to the instrument.

Questionnaire 2

Questionnaire 2 was designed to address Research Question 5 by exploring the influence of the protocol on engineering faculty definitions of contextual competence. It was also designed to determine whether the faculty thought that the study results would be useful for academic program improvement. The questionnaire items were developed using 70 outcome attributes of contextual competence obtained from Questionnaire 1, item 1. Each outcome attribute was adapted into an item for Questionnaire 2, and the items were subsequently organized into seven themes. A copy of Questionnaire 2 can be found in Appendix D. Each item was presented in a checklist format in which the respondents were asked to select from the following:

1. The attribute is desirable for inclusion in the definition of contextual competence (outcome h) as applied to graduates of the undergraduate chemical engineering program
2. The attribute should be evaluated by chemical engineering faculty within their courses and incorporated into a self-study on outcome (h) as required for accreditation by ABET
3. The attribute is desirable, but should not be included in the definition of contextual competence (outcome h)

If respondents believed that the outcome attribute was not desirable, they were asked to leave the item blank. Two final items on Questionnaire 2 were in “yes/no” format and asked (1) if completion of the two questionnaires in the study changed their understanding and definition of the concept of contextual competence, and (2) if they would use the results of the study in their undergraduate engineering program.

Pilot Test, Questionnaire 2. The first draft of Questionnaire 2 presented the outcome attributes in a “yes/no” format, asking the respondents simply to identify those outcome attributes they would include in a definition of contextual competence for their academic program. The draft questionnaire was completed by two engineering faculty members. Both reviewers commented on the tendency to include all outcome attributes in the definition. They explained that while some outcome attributes might be included in the definition, they would not necessarily be assessed (meaning that not all outcome attributes were equal). The questionnaire was revised to a checklist format that included response categories for those outcome attributes the respondents would include in the definition of contextual competence, those they would include in the definition and assess as part of an ABET self study, and those they found desirable, but not for the definition of contextual competence. The time required to complete the revised questionnaire was approximately 25 minutes.

Data Collection

The case study included three sequential phases of data collection. The data collection and analysis procedures for the faculty selection process were described previously under Selection of the Case. The second phase of data collection involved the implementation of Questionnaire 1 with both CHE and HSS faculty members, and the third phase focused on the implementation of Questionnaire 2 with CHE faculty members. The procedures for implementation of both questionnaire instruments are described in this section.

Questionnaire 1

The respondents received the questionnaire packages from the chair of the school or the dean of the college in March 2004. The researcher assigned each faculty member an alphanumeric code and marked each questionnaire with the appropriate code for the recipient of the questionnaire package. The questionnaire package included a letter of invitation from the chair or dean addressed to each faculty member by name, an instruction sheet, two copies of the consent form approved by the Office of Human Subjects, the questionnaire instrument, and the sample verb list. The researcher assembled the questionnaire packages and placed them in the departmental mailboxes for each faculty member selected for the study. The respondents were given ten days to complete the questionnaire. The researcher collected the completed questionnaires and consent forms from each respondent directly or from the department secretary, as indicated by the respondent. One week following the distribution of the questionnaire packages, the researcher sent a follow-up message by electronic mail to the faculty. After collection of the completed questionnaires on the due date, the researcher sent an additional reminder by electronic mail to each faculty member not completing the questionnaire. All electronic mail messages were addressed directly to each faculty member, and the main text of the messages was the same for both groups of faculty. Seventy-one percent of the CHE faculty responded by the due date, and 83% after the second reminder notice. For the HSS faculty, 46% responded by the due date, and 58% after the second reminder notice. Upon receipt of the completed questionnaires and forms, the researcher separated the consent forms from the coded questionnaires and maintained the consent forms and code list in a separate location from the questionnaire and other study data.

Questionnaire 2

The 20 respondents in the School of Chemical and Biomolecular Engineering who completed Questionnaire 1 received the second questionnaire in the protocol in August 2004. The time between distribution of Questionnaires 1 and 2 was four months, the time needed to complete the analysis of Questionnaire 1 and generate the outcome attributes for inclusion in Questionnaire 2. The questionnaire package included a cover letter from the researcher addressed to each faculty member by name, the questionnaire instrument, and a four-piece box of Godiva^{TM} chocolates as an incentive to complete the questionnaire. The questionnaires were coded, assembled into packages, and distributed using the same procedures as those described for Questionnaire 1. The researcher contacted each faculty member by electronic mail to invite them to participate. The electronic message used the same text as the cover letter, amended to indicate that the questionnaire packages had been delivered to the departmental mailboxes. The CHE respondents were given 20 days to complete the questionnaire, and the completed questionnaires were collected by the researcher from the department secretary. Seventeen of the CHE faculty completed Questionnaire 2 (85% response rate).

Data Analysis Procedures

The data from Questionnaires 1 and 2 were analyzed using Microsoft Word and Excel^{TM} software programs. Responses to the open-ended items 1, 2 and 3 on Questionnaire 1 were analyzed using a comparative analysis technique described by Merriam (Merriam, 1988). Response frequencies were counted and descriptive statistics computed for the responses to the multiple choice, checklist, and yes/no format items in Questionnaires 1 and 2. A detailed description of the data analysis procedures for each questionnaire item, organized by research question, is provided in Appendix E for those interested in replication of the study.

Verification

The trustworthiness, authenticity, dependability, and transferability of the study results determine the quality and relevance of the study for use in program improvement (Greene, 1994, p. 535). The trustworthiness of the study was assured through pilot testing and expert assessment of the protocol design and questionnaire instruments. The authenticity of the study, defined in the constructivist tradition (Guba & Lincoln, 1994, p. 112), was assessed using CHE faculty data from Questionnaires 1 and 2 to determine if participation in the two-questionnaire protocol met the criteria for authenticity. The criteria are as follows:

1. Participation enlarged personal constructions (ontological authenticity). This was defined as the change in the number and type of outcome attributes each faculty member selected to include in his or her definition of contextual competence (Research question 5).
2. Participation led to improved understanding (educative authenticity). This was assessed using faculty self-reports on whether participation in the study changed their understanding and definition of the concept of contextual competence (Questionnaire 2, item 8a).
3. Participation stimulated respondents to action (catalytic authenticity) or empowered action (tactical authenticity). This was assessed using information on whether faculty perceive a need to change the emphasis on contextual competence in courses (Questionnaire 1, items 5 and 6); and faculty self-reports on whether they would use the results of the study in their undergraduate engineering program (Questionnaire 2, item 8b).

The dependability of the study results was assured through the development and implementation of a formal case study protocol that included procedures for collecting field data (Yin, 1994).

Table 6. Undergraduate Chemical Engineering Curriculum

Term Recommended	Course (Department, Number, Title)	Required Courses Taught by Chemical Engineering Faculty	Core Curriculum Courses in the Humanities and Social Sciences
First Year	Math 1501 Calculus I		
1st Semester	Chem 1310 General Chemistry		
	Eng 1101 English Composition I		
	Hist 2111or 2112 or Pol 1101 or PubP 3000 or IntA 1200		Social Sciences (Area E)
	HPS 1040/1062/1063/1064		
First Year	Math 1502 Calculus II		
2nd Semester	Chem 1311 Inorganic I		
	Chem 1312 Inorganic Lab		
	Eng 1102 Composition II		
	Phys 2211 Introduction to Physics I		
	CS 1321 Introduction to Computing		
Second Year	Math 2401 Calculus III		
1st Semester	Phys 2212 Introduction to Physics II		
	Chem 2311 Organic Chemistry I		
	ChBE 2100 Chemical Process Principles	CHE Core	
	Econ 2100 Economics and Policy		Social Sciences (Area E)
Second Year	Math 2403 Differential Equations		
2nd Semester	Chem 2312 Organic Chemistry II		
	Chem 3412 Physical Chemistry II		
	ChBE 2110 Chemical Engineering Thermodynamics I	CHE Core	
	ChBE 2120 Numerical Methods	CHE Core	
Third Year	ChBE 3110 Chemical Engineering Thermodynamics II	CHE Core	
1st Semester	ChBE 3200 Transport Processes I	CHE Core	
	Chem 2380 Synthesis Lab		
	MSE 2001 Engineering Materials		
	Elective (Social Science)		Social Sciences (Area E)

Term Recommended	Course (Department, Number, Title)	Required Courses Taught by Chemical Engineering Faculty	Core Curriculum Courses in the Humanities and Social Sciences
	Elective (Free)		
Third Year 2nd Semester	ChBE 3210 Transport Processes II	CHE Core	
	ChBE 4300 Kinetics and Reactor Design	CHE Core	
	Chem 3281 Instrumental Analysis		
	Elective (Social Science)		Social Sciences (Area E)
	Elective (Technical)		
Fourth Year 1st Semester	ChBE 3225 Separation Processes	CHE Core	
	ChBE 4400 Process Control	CHE Core	
	ChBE 4515 Process Safety	CHE Core	
	Elective (Free)		
	Elective (Humanities)		Humanities (Area C)
	Elective (Technical)		
Fourth Year 2nd Semester	ChBE 4200 Transport Phenomena/Unit Operations Lab	CHE Core	
	ChBE 4505 Process Design and Economics	CHE Core	
	Elective (ChBE)		
	Elective (Humanities)		Humanities (Area C)
	Elective (Technical)		

Table 7. Chemical Engineering Faculty Characteristics

	CHE Sample (N=24)		Respondents to Questionnaire 1 (N=20)		Respondents to Questionnaire 2 (N=17)	
Type of Institution Attended	B.S. (%)	Ph.D. (%)	B.S. (%)	Ph.D. (%)	B.S. (%)	Ph.D. (%)
Technology-Oriented Institution	42	46	45	40	41	41
State Land-Grant Institution	33	41	35	45	35	47
Other Institution	25	13	20	15	24	12
B.S. at U.S. Institution	79		80		76	
Faculty Rank	(%)		(%)		(%)	
Assistant Professor	17		20		18	
Associate Professor	25		25		23	
Full Professor	58		55		59	
Other Characteristics	(%)		(%)		(%)	
Experience in Industry/Government	54		55		53	
Registered Professional Engineer	8		10		12	
Doctoral Degree Awarded < 1982	50		50		53	
Doctoral Degree Awarded >1982	50		50		47	

Table 8. CHE Respondents' Teaching Experience with the Required Undergraduate Chemical Engineering Courses (N = 20)

Course Title	Course Number	Sections Taught by Respondents 2000-2004, %
Chemical Process Principles	CHBE 2100	55
Chemical Engineering Thermodynamics I	CHBE 2110	53
Numerical Methods	CHBE 2120	59
Chemical Engineering Thermodynamics II	CHBE 3110	71
Transport Processes I	CHBE 3200	100
Transport Processes II	CHBE 3210	25
Separation Processes	CHBE 3225	100
Transport Phenomena/Unit Operations Lab	CHBE 4200	100
Kinetics and Reactor Design	CHBE 4300	59
Process Control	CHBE 4400	100
Process Design and Economics	CHBE 4505	63
Process Safety	CHBE 4515	100

Table 9. Humanities and Social Science Courses Taken by Chemical Engineering Students Graduating May 2003 (N = 31)

	Number of Courses		Range	
Subject Area	Average	Median	Minimum	Maximum
Social Sciences	5	5	2	9
Humanities	3	2	0	8
Total	8	8	2	16

Table 10. Proportion of Course Enrollments in Humanities and Social Sciences Subjects by Students in Chemical Engineering Cohort (N=31)

	Total	As a Percentage of Enrollments in:	
Course Enrollments in Each Subject in Humanities		All HSS Courses (N = 242)	Humanities (N = 89)
	N	(%)	(%)
Architecture, City Planning, Industrial Design, Music	21	9%	24%
Literature, Communication and Culture	21	9%	24%
Modern Languages	37	15%	42%
Philosophy of Science and Technology	10	4%	11%
Course Enrollments in Each Subject in Social Sciences		All HSS Courses (N = 242)	Social Sciences (N = 153)
	N	(%)	(%)
Architecture, City and Regional Planning	3	1%	2%
Economics	45	19%	29%
History, Sociology, and History, Technology and Society	32	13%	21%
International Affairs	9	4%	6%
Political Science and Public Policy	16	7%	10%
Psychology	48	20%	31%

Table 11. The Number of Humanities and Social Sciences Faculty in Each Subject Solicited for Participation in the Study and Responding to Questionnaire 1

	Number Identified by the College	Number Responding to Questionnaire 1
Humanities Faculty		
Literature, Communication and Culture	2	1
Modern Languages	3	1
Philosophy of Science and Technology	1	1
Social Sciences Faculty		
Economics	4	2
History, Sociology, and History, Technology & Society	4	2
International Affairs	2	2
Political Science and Public Policy	3	2
Psychology	4	3
Total Number of HSS Faculty	24	14
	100%	58%

Table 12. Experience of Respondents in the Humanities and Social Sciences with Teaching the HSS Courses Taken by CHE Students in the May 2003 Graduating Cohort (N = 14)

	Number of HSS Respondents Indicating Experience Teaching:	
Disciplinary Affiliation of the HSS Respondents	HSS Courses Taken Most Often	Other HSS Courses
Humanities Faculty		
Literature, Communication and Culture		1
Modern Languages	1	1
Philosophy of Science and Technology		1
Social Sciences Faculty		
Economics	1	1
History, Sociology, and History, Technology & Society	1	2
International Affairs	2	1
Political Science and Public Policy	2	
Psychology	3	1
Total	10	8
% of HSS Respondents with Experience Teaching HSS Courses	71%	57%

CHAPTER 4

FINDINGS

The findings from the faculty responses to the two questionnaires in the protocol are reported in this section. The findings are organized by the five research questions posed by this study, and begin with the data on the social connectedness of the respondents.

Faculty Background in Curriculum Activities

The general education policy of the institution was an important factor in selection of the case study site. It was assumed that the general education policy would influence not only the level of integration in learning between general education and the major, but also the level of interaction between faculty members in the major and general education curriculum components. The respondents' interactions in curricular activities are an important characteristic of the faculty participating in the study as they influence the extent to which the respondents present discipline-oriented versus multidisciplinary perspectives on contextual competence. Faculty interactions were examined in two ways: through reporting on curriculum-related activities and through the types of contacts the respondents identified as sources they would seek for more information on contextual competence.

Faculty Interactions

The CHE and HSS faculty responses to questions about their involvement in formal curricular discussions regarding the humanities and social sciences component of the engineering curriculum (item 8 of Questionnaire 1) are summarized in Table 13. A majority of the HSS respondents served on formal curriculum committees that deliberated the humanities and social sciences courses taken by engineering students, compared to less than one-third of the CHE respondents. A similar proportion of HSS and CHE respondents participated in formal faculty discussions that deliberated the humanities and social science courses taken by engineering students (43% and 40% respectively). Formal faculty discussions are defined as meetings convened for the purpose of discussing the curriculum. A small proportion of the respondents from either group of faculty participated in such discussions or served on committees at the university level where discussions would involve faculty from both general education and the major. A very small proportion of respondents from either group of faculty taught an interdisciplinary course or participated as an investigator in an interdisciplinary research project involving the undergraduate engineering curriculum (Table 14).

Many of the respondents have discussed contextual competence or other multidisciplinary outcomes with their colleagues. As shown in Table 15, a majority of the respondents in both groups of faculty participated in discussions with colleagues about contextual competence and how students would develop it. Only a small proportion of HSS respondents reported discussing specific socio-humanistic objectives of engineering courses with members of the engineering faculty.

The engineering faculty have the opportunity to discuss contextual competence as part of program review and self-study activities for accreditation by ABET. Among the CHE respondents, however, very few reported participating on an external review committee for ABET. A small proportion of the CHE respondents reported participating on internal program review committees or ABET self-study committees for academic programs administered by the School of Chemical and Biomolecular Engineering.

Contacts Related to Contextual Competence

Fifteen of the 20 CHE respondents identified 39 individuals from whom they would seek more information about contextual competence, and 12 of the 14 HSS respondents identified 34 individuals (item 9 of Questionnaire 1). Table 16 shows the distribution of the contacts by discipline (engineering, humanities and social sciences, or other) and institutional affiliation. The CHE respondents were more likely to contact a colleague in engineering for information about contextual competence (90% of all CHE contacts), and the HSS respondents were more likely to contact a colleague in the humanities and social sciences (71% of all HSS contacts). Nearly half of the contacts identified by CHE respondents and three-quarters of the contacts identified by HSS respondents were located at Georgia Tech. Half of the contacts identified by the respondents were located in their same academic unit as the respondent.

Table 17 shows the proportion of respondents who identified contacts from their own and other disciplines, at Georgia Tech and at other institutions. The majority of respondents from either the CHE or HSS faculty group identified at least one contact from their own faculty group at Georgia Tech. Over half of the HSS respondents identified at least one contact in engineering, and 13% of the CHE respondents identified at least one contact from the humanities and social sciences. Nearly three-quarters of the CHE respondents identified contacts only from engineering, and slightly less than half of the HSS respondents identified contacts only from the humanities and social sciences. One-third of the CHE respondents identified contacts located only at other institutions.

Research Question 1: Definition of Contextual Competence

> How do faculty members in engineering and in the humanities and social sciences define contextual competence?

Definition of Contextual Competence: Questionnaire 1

The definitions of contextual competence provided by the respondents in Questionnaire 1 yielded a total number 117 attributes in seven thematic categories: technology and society, diverse cultures and values, engineering practice and decision making in context, economics, safety, human behavior and technology, and ethics (Table 18). Attributes addressing the same or similar topics, and reflecting competencies at similar levels of intellectual development, were combined into a single outcome attribute. After combination of similar attributes, the list of attributes was reduced to 70 distinct outcome attributes for contextual competence. The statistics related to the definition of contextual competence are reported in terms of the identification of an outcome attribute by a respondent in his or her definition of contextual competence, i.e., the respondent identified an attribute in his or her definition that was combined with similar attribute statements identified by other respondents into a final outcome attribute. The average CHE respondent identified five of the 70 outcome attributes (the combined list of outcome attributes identified by the respondents). The lowest number of attributes identified by a CHE respondent in his or her definition of contextual competence was one and the largest number of attributes identified was ten. The average HSS respondent identified three of the 70 outcome attributes, with a minimum of one attribute and a maximum of six attributes.

The “source of contribution” of the outcome attributes was determined by the disciplinary affiliation of all of the respondents who identified the attribute in his or her definition of contextual competence. Some attributes were identified only by engineering respondents, some only by HSS respondents, and some were identified by respondents from both groups of faculty.

The distribution of the outcome attributes by theme and by source of contribution is presented in Table 19. Thirty-four of the 70 outcome attributes were identified by engineering respondents only, 26 by HSS respondents only, and 10 by respondents from both groups of faculty. Summary statistics on the number of outcome attributes identified by CHE respondents, distributed by source category, were calculated for the CHE respondents. On average, the definition of contextual competence provided by each of the CHE respondents in Questionnaire 1 included 4 of the 34 outcome attributes identified only by engineering faculty, none of the 26 outcome attributes identified only by faculty in the humanities and social sciences, and 1 of the 10 outcome attributes identified by respondents from both groups of faculty.

Overall, the respondents identified the largest number of outcome attributes in the thematic area of engineering practice and decision making in context (20 attributes). When ranked by the number of outcome attributes identified in each thematic area, the areas fell in the following order: diverse cultures and values (11), ethics and the engineering profession (10), economics and business (9), technology and society (9), safety (7), and human behavior and technology (4). The similarities and differences in the definition of contextual competence between the two groups of faculty respondents are determined by examining the content of the outcome attributes they identified in each thematic area. The most significant similarities and differences are discussed in this section. The outcome attributes, including the attribute number as presented as checklist items in Questionnaire 2, are presented in Table 20.

Technology and society. Both CHE and HSS respondents identified outcome attributes on the relationship between technology and society (outcome attributes 1a through 1c). Within this set of outcome attributes, only CHE respondents specifically mentioned environmental issues and sustainability (outcome attribute 1f), and only HSS respondents mentioned reading and discussion of scholarly texts (1h). CHE respondents also identified outcome attributes related to learning the history behind a technology (1d) and the ability to deliver a thoughtful seminar on the broader context of a technology (1g).

Diverse cultures and values. Nearly all of the outcome attributes related to diverse cultures and values were identified by the HSS respondents only. Respondents from both groups of faculty identified the outcome attribute related to the ability to appreciate and respect the importance of multiple perspectives and enjoy debating with individuals that express different perspectives in frank discussions (2e). Among the outcome attributes in this set several focus on the ability to

- appreciate and understand diverse cultures, values and attitudes (2a and 2b);
- understand that values are embodied in engineering design and practice (2c); and
- understand how diverse populations are affected by the engineering world (2d).

Engineering practice and decision making in context. CHE respondents identified twice as many outcome attributes as the HSS respondents related to engineering practice and decision making in context. The largest group of outcome attributes identified by CHE respondents was related to the ability to identify, assess and evaluate both qualitative and quantitative impacts of products and processes (3c through 3g). Within this set of outcome attributes, only CHE respondents mentioned the ability to consider economic impacts and commercialization, ethical issues, safety issues, and environmental issues and sustainability in the assessment of products and processes (3c though 3f). Respondents from both groups of faculty identified the need to consider competing interests and values at stake in a project, including those which are not necessarily voiced (3g, and also in 3l). Only HSS respondents identified the outcome attributes in this set related to strategic planning and decision making (3q through 3t).

Economics and business. The main distinction between the outcome attributes identified by CHE versus HSS respondents in the economics and business area was the emphasis the CHE respondents placed on application of economic concepts to specific engineering projects (4c, 4d, 4f, and 4h). Respondents from both groups of faculty identified outcome attributes related to understanding micro- and macroeconomics in a decision making context (4a and 4b), and the ability to allocate resources (4e). The HSS respondents identified two related outcome attributes: the ability to anticipate how social forces will affect the implementation, success and acceptance of engineering solutions (4g), and the ability to respect cultural differences in dealing with business partners (4i).

Safety. The CHE respondents identified all of the outcome attributes related to safety. These attributes address some aspect of risk and safety issues associated with chemical processes, products, or facilities in the broader societal context (5a and 5b). Several focus on the specific skills needed by the practicing engineer for risk management, e.g., the ability to assess the balance between the need for public safety and the need for a new technology, the ability to recognize and avoid use of toxic materials, or the ability to design safety systems or protocols (5c through 5g).

Human behavior and technology. Three of the four outcome attributes in the human behavior and technology area were identified by HSS respondents only. These outcome attributes include the understanding of various theories of human and social behavior (6a), the ability to challenges one’s own beliefs about human behavior and values (6b), and the ability to assess the impact human factors can have on the effectiveness of an engineering solution (6d). Respondents from both groups of faculty identified one outcome attribute on the ability to identify the human factors (human psychology, errors, and uncertainties) involved in the development of an engineering solution (6c).

Ethics and the engineering profession. Respondents from both groups of faculty identified outcome attributes in ethics and the engineering profession. The main distinction between the outcome attributes identified by the CHE respondents and those identified by the HSS respondents is the emphasis placed by the CHE respondents on ethics in the context of professional practice. The outcome attributes identified by the HSS respondents include the ability to

- articulate fundamental principles of ethical reasoning (7c);
- evaluate science and technology based activities and outcomes from ethical perspectives (7d); and
- analyze and evaluate historical and/or hypothetical case studies (7e).

The outcome attributes oriented towards professional practice identified by the CHE respondents include the ability to

- understand the need for ethical professional behavior, to exhibit critical thinking when presented with an ethical situation, and make engineering judgments that are consistent with professional practice (7f); and
- distinguish ethical and social considerations from matters of expediency and self interest and defend a position on the side of due diligence even when such a position may be contrary to the wishes of his or her superiors (7h through 7j).

Definition of Contextual Competence: Questionnaire 2

Questionnaire 2 was distributed only to CHE faculty who responded to the first questionnaire. Seventeen of the 20 CHE respondents who completed Questionnaire 1 responded to the second questionnaire (85% response rate). Each of the 70 outcome attributes from Questionnaire was transformed into an item on Questionnaire 2. For each of the items/outcome attributes, the respondents were asked to select one of the following responses:

1. The attribute is desirable for inclusion in the definition of contextual competence (outcome h) as applied to graduates of the undergraduate chemical engineering program;
2. The attribute should be evaluated by chemical engineering faculty within their courses and incorporated into a self-study on student outcomes as required for accreditation by ABET;
3. The attribute is desirable, but should not be included in the definition of contextual competence (outcome h).

Table 21 shows the number of outcome attributes selected by a majority of the respondents for each response category, and the number of outcome attributes not selected as desirable by a majority of the respondents. The table includes the total number of outcome attributes and the number of attributes distributed by the source category of the attribute.

The CHE respondents selected 44 of the 70 outcome attributes as desirable for inclusion in the definition of contextual competence as applied to graduates of the undergraduate chemical engineering program. When distributed by source category, the outcome attributes selected by the respondents include 26 of the 34 outcome attributes identified (in Questionnaire 1) by engineering respondents only, 12 of the 26 outcome attributes identified by HSS respondents only, and 6 of the 10 outcome attributes identified by respondents from both groups of faculty. Of the 44 outcome attributes selected for the definition of contextual competence, 21 were selected by the CHE respondents for evaluation within their courses and incorporation into a self-study on outcome (h) as required for accreditation by ABET. Table 22 shows the 44 (of 70) outcome attributes selected by a majority of the CHE respondents to include in the definition of contextual competence. Each attribute is listed by theme and by source category. The table also indicates whether the attribute was selected for evaluation and incorporation in an ABET self-study.

Sixteen of the 70 outcome attributes were selected by a majority of the CHE respondents as desirable, but not as part of the definition of contextual competence. These outcome attributes are shown in Table 23. The remaining 10 (of 70) outcome attributes were not selected by a majority of the respondents in any of the response categories. These outcome attributes, and the percentage of respondents selecting the two “desirable” response categories, are displayed in Table 24. The data in Table 24 show that many of these 10 attributes are considered desirable by the CHE respondents (determined by the sum of the respondents selecting the two “desirable” response categories), but that the respondents do not agree on whether the attributes should be included in the definition of contextual competence.

The following paragraphs review the behavior of the CHE respondents in the selection of outcome attributes in each thematic area for inclusion in the definition of contextual competence and for evaluation as part of a self-study for ABET accreditation.

<u>Technology and society.</u> CHE respondents selected six out of the nine attributes related to technology and society to include in the definition of contextual competence. All of the respondents selected outcome attribute (1f), and a majority of the respondents indicated that the outcome should be evaluated and included in a self-study for ABET accreditation. Outcome attribute (1f), which was identified (in Questionnaire 1) by engineering respondents only, states that students should be able to

- understand issues of sustainability and the impact of professional engineering work on the production of global, societal well-being (in terms of economic, ethical and environmental quality) and quality of life (in terms of convenience, health, environment, safety, and the economy).

Two of the three remaining outcome attributes from the technology and society set, related to history of technology, were selected by the CHE respondents as desirable, but not for the definition of contextual competence. One attribute, the ability of students to deliver a thoughtful seminar on the broader societal context of a technology (1g), was not selected by a majority of respondents in any category.

Diverse culture and values. CHE respondents selected only one of the 11 outcome attributes from the diverse cultures and values set to include in the definition of contextual competence. They selected outcome attribute (2c) for inclusion in the definition but not for evaluation and incorporation in a self-study for ABET accreditation. Outcome attribute (2c), which was identified (in Questionnaire 1) by HSS respondents only, states that students should be able to

- understand the social and cultural values that are *embodied in* engineering design and practices, including how engineering practices depend on assumptions about the characteristics of users (e.g., their education, attitudes, wealth, goals) and their societies (e.g., how economic or political processes will put a technology into practice).

CHE respondents selected seven of the outcome attributes in the diverse cultures and values set as desirable, but not for the definition of contextual competence. The ability to speak a foreign language (2f), to write critical essays on social issues (2j), and muster evidence to substantiate opinion (2k) were not selected by a majority of respondents in any category. The responses for

(2f) and (2k) fell just short of a majority, at 47% each, for the category “desirable, but not for the definition of contextual competence.”

Engineering practice and decision making in context. CHE respondents selected 19 of the 20 outcome attributes related to engineering practice and decision making in context to include in the definition of contextual competence, and 14 of those selected were also selected for evaluation and incorporation in a self-study for ABET accreditation. The CHE respondents would evaluate the outcome attributes associated with a student’s ability to assess and evaluate the qualitative and quantitative impacts of products and processes (3a through 3f), to optimize a design using contextual variables (3h), justify and defend tradeoffs (3k), and communicate results to appropriate groups (3p). Only one attribute in this category was selected as desirable, but not for the definition of contextual competence.

Eight of the 19 selected outcome attributes in the engineering practice set were identified in Questionnaire 1 by HSS respondents only, or by respondents in both faculty groups. Of these, three outcome attributes address the ability of students to include the interests, values, and needs of the larger community in the assessment of engineering projects (3g, 3j and 3l). One of these three outcome attributes was selected for evaluation and incorporation in a self-study for ABET accreditation (3l). Outcome attribute (3l) states that students should be able to

- defend or challenge a proposed engineering solution based upon a broad and deep assessment of the needs and claims of all parties involved.

Another attribute selected from the HSS-only source category is related to the ability of the students to predict the range of possibilities that an engineering solution could have within a global and societal context (3i). The four remaining outcome attributes selected for inclusion in the definition were also selected by a majority of the respondents for evaluation and incorporation in a self-study for ABET accreditation. Outcome attributes (3q) through (3t) were identified (in Questionnaire 1) by HSS respondents only, and focus on strategic planning and decision making skills requiring students to be able to

- effectively synthesize and analyze knowledge and apply it to a decision context,
- evaluate the outcomes of their decision; and
- implement their decisions on an individual basis and by working in groups in both face-to-face and electronic group contexts.

Economics and business. CHE respondents selected five of the nine outcome attributes in the economics and business area for inclusion in the definition of contextual competence, but none of the outcome attributes were selected for evaluation and incorporation in a self-study for ABET accreditation. All five address economics and engineering in a global and societal context. The selected outcome attributes include the ability to

- understand micro- and macroeconomics and their relationship to decision making in the technology arena (4a);
- understand resource distribution, allocation of scarce resources and the cultural impacts from engineering projects (4d); and
- judge engineering solutions to a problem in context (4f).

Two of the outcome attributes, one identified (in Questionnaire 1) by engineering respondents only and the other by HSS respondents only, relate to a student’s ability to anticipate and respond to the social consequences of engineering projects (outcome attributes 4h and 4g respectively). These two outcome attributes state that students should be able to

- anticipate how social forces (economic and business, sociological, historical, ethical, environmental and political) will affect the implementation, success, and acceptance of engineering solutions (4g); and
- judge whether or not engineering solutions should be introduced, recalled, or otherwise adapted (4h).

In the economics and business set, two outcome attributes were selected by the CHE respondents as desirable, but not for the definition of contextual competence. One involved the ability to perform economic analyses from a national level to the engineering project level (4b). The other outcome attribute bridged between economics and diversity, requiring students to be able to

- respect intercultural and international differences in dealing with business partners. They should be able to generate business proposals and evaluate business situations based on background knowledge of such differences (4i).

The remaining two outcome attributes in the set fell just short of selection by a majority into any response category. The ability to assess the societal impacts of outsourcing (4c), and to allocate resources and determine price-quantity combinations (4e), were both selected by 47% of the CHE respondents as desirable, but not for the definition of contextual competence.

Safety. The CHE respondents selected all seven of the outcome attributes in the safety set for inclusion in the definition of contextual competence. With the exception of outcome attribute (5g), the ability to explain the role of the engineering in public safety, all of the outcome attributes were selected for evaluation and incorporation in a self-study for ABET accreditation. Two of these attributes were selected by all of the CHE respondents (5a and 5d). These attributes state that students should be able to

- assess the risks and safety issues associated with any chemical process, product, or facility in the broader societal context, and raise the safety issues as questions for discussion (5a); and
- recognize toxic or ecologically persistent materials if these are involved in a proposed process, and be able to predict if such materials are likely to be formed under the proposed conditions (5d).

Human behavior and technology. None of the four outcome attributes in human behavior and technology area were selected by a majority of the CHE respondents for inclusion in the definition of contextual competence. Three were selected by the CHE respondents as desirable, but not for the definition of contextual competence. These include the ability to discriminate among theories of human and social behavior (6a), to challenge one’s own beliefs about human behavior and values (6b), and to assess the impact of human factors on the effectiveness of an engineering solution (6d). The fourth outcome attribute, on the ability to identify human factors involved in the development of an engineering solution (6c), was not selected by a majority of respondents in any response category.

Ethics and the engineering profession. CHE respondents selected six of the ten outcome attributes in the ethics and the engineering profession set for inclusion in the definition of contextual competence. None of the outcome attributes was selected by a majority of the respondents for evaluation and incorporation in a self-study for ABET accreditation. Three of the outcome attributes were identified (in Questionnaire 1) by HSS respondents only, and these reflect general ethics competencies such as the ability to articulate the fundamental principles of ethical reasoning (7c), to evaluate science and technology activities from ethical perspectives (7d), and to analyze and evaluate case studies (7e). The other three outcome attributes were identified by engineering respondents only and focused on the students' roles as good citizens (7a) and responsible professionals (7b and 7f). Specifically, the respondents believe that students should be able to

- understand the need for ethical professional behavior, exhibit critical thinking when presented with an ethical situation, and be willing to make engineering judgments and decisions that are ethically correct and consistent with accepted professional practice (7f).

A fourth outcome attribute was not selected by a majority of respondents in any response category, falling just short of a majority for inclusion in the definition of contextual competence (at 47%). This attribute addresses the ability to comprehend the factors associated with sound leadership and ethical behavior and differentiate between leadership and management (7g), and was identified (in Questionnaire 1) by HSS respondents only.

The remaining three outcome attributes relate to the ability of students to distinguish ethical and social considerations from matters of expediency or self interest. Outcome attribute (7i), on the ability to defend a position on the side of due diligence, was selected as desirable, but not for the definition of contextual competence. Outcome attribute (7j), the ability to resolutely and passionately support engineering solutions that are fundamentally correct and socially beneficial, fell just short of a majority of respondents who selected it as desirable, but not for the definition of contextual competence (at 47%). The third outcome attribute (7h) was not selected by a majority in any response category.

Research Question 2: Courses in which Contextual Competence is Developed

> In which courses in the undergraduate curriculum do faculty members in engineering and in the humanities and social sciences believe contextual competence is best developed?

Both CHE and HSS faculty participants were asked how students would best develop contextual competence in the courses in the undergraduate curriculum (Questionnaire 1, item 4). The results are shown in Table 25. A large number of respondents from both groups of faculty indicated that students would best develop contextual competence though coursework in both engineering and the humanities and social sciences (85% of the CHE respondents and 65% of the HSS respondents). They differed in opinion as to whether the development would occur through courses primarily in engineering (75% of the CHE respondents versus 22% of the HSS respondents) or in the humanities and social sciences (10% of the CHE respondents versus 43% of the HSS respondents). A small proportion of respondents from either group of faculty indicated that the development would best occur in humanities and social science courses only, and no respondents indicated that it would best occur in engineering courses only. The respondents who selected “other” commented that contextual competence would be developed equally through coursework in both engineering and the humanities and social sciences. One respondent explained his response:

> Engineering and contextual competence must be learned together, or the curriculum will be an example of the problem, namely the separation of the two realms.

The CHE respondents were asked to use a five-point rating scale to describe each of the 12 required chemical engineering courses in terms of the emphasis placed on the development of contextual competence. The results are displayed in Figure 1. A majority of the CHE respondents identified six courses in which contextual competence was a major or minor objective of the course. The respondents identified two courses in which contextual competence was viewed as a major objective, Process Design and Economics (CHBE 4505) and Process Safety (CHBE 4515).

The course ratings were analyzed to compare the ratings of respondents who have taught the courses versus those who have not taught them. The results are shown in Table 26. The CHE respondents rated the courses at the same level of emphasis for six of the 12 chemical engineering courses, including the two courses identified as placing a major emphasis on contextual competence. For the remaining six courses, the differences in ratings did not reflect major differences between the respondents who have taught the courses versus those who have not taught them (e.g., the difference in opinion was between a minor and informal emphasis or between an informal emphasis to not an objective).

The HSS respondents were asked to identify and rate courses in their respective departments that they thought would best contribute to the development of contextual competence in engineering students. The list of courses in which contextual competence is a major objective includes 24 specific courses and courses in modern languages (Table 27). The respondents identified seven courses in science, technology and society, and four courses in ethics and human values. The list also includes the most common humanities and social science courses taken by the cohort of chemical engineering students who graduated in May 2003. The courses were Economics and Policy (ECON 2100), American Government (INTA 1200), Science, Technology and Human Values (PST 3127), and General Psychology (PSY 1101). While the HSS respondents did not specifically mention environmental protection or sustainability in the outcome attributes they identified in Questionnaire 1, they did identify four courses on those topics as having contextual competence as a major objective, and three courses in which it was a minor objective. The list of courses in which contextual competence is a minor objective is shown in Table 28, and the list of courses in which it is addressed informally is shown in Table 29.

Research Question 3: Level of Emphasis Placed on Contextual Competence

> Do faculty in engineering and in the humanities and social sciences believe that adequate emphasis is placed on contextual competence in courses in engineering or in courses in the humanities and social sciences?

The respondents were asked to give their opinion on the overall level of emphasis on contextual competence, what it is and what it should be, in the required chemical engineering courses (items 5a and 5b respectively) and in the courses in the humanities and social sciences taken by engineering students (items 6a and 6b respectively).

Emphasis in the Chemical Engineering Courses

The CHE and HSS responses on the chemical engineering courses are shown in Table 30 and Table 31 (items 5a and 5b of Questionnaire 1). A majority of the CHE respondents (60%) indicated that there was some emphasis on contextual competence in the chemical engineering courses, but the emphasis was inadequate. They were of the opinion that more emphasis should be placed on contextual competence in the chemical engineering courses. One CHE respondent who indicated that more emphasis should be placed on contextual competence cautioned that “there is always room for improvement, but the costs do not necessarily outweigh the benefits.”

The HSS respondents were split in their opinion as to whether the emphasis on contextual competence was adequate in the chemical engineering courses (43% thought it was inadequate, 36% thought it was adequate). The comments provided by the HSS respondents suggest that the issue may not be the amount of emphasis on contextual competence, but the level of integration of the content between courses in engineering and the humanities and social sciences. One HSS respondent who commented on integration responded that there should be more emphasis placed on contextual competence in the chemical engineering courses:

> Integration is inadequate. We cannot assume that if we teach A, and they teach B, that students will miraculously discover how A relates to B.

Similar comments were provided by two other HSS respondents who indicated that the amount of emphasis on contextual competence in the chemical engineering courses should be the same as it currently is:

> The emphasis is there, but is not necessarily focused on the particular requirements of outcome h [contextual competence]. It's more a matter of how we teach context, not how much. There is not always explicit concern with helping engineers to understand their own work.
>
> There is some emphasis on developing contextual competence, the level is adequate in terms of the quality and quantity of information, but the link between engineering training and contextual competence is not drawn adequately.

A majority of respondents from both groups of faculty selected logically consistent responses between items 5a and 5b of Questionnaire 1. 60% of the CHE respondents and 36% of the HSS respondents selected the “some emphasis, but inadequate” and “more” combination; and 15% of the CHE respondents and 36% of the HSS respondents selected the “some emphasis, and adequate” and “same” combination.

Emphasis in Courses in the Humanities and Social Sciences

Table 32 and Table 33 present the responses of both CHE and HSS respondents on the level of emphasis on contextual competence in courses in the humanities and social science courses taken by engineering students (items 6a and 6b of Questionnaire 1). The CHE responses were split, with 55% indicating that there was either no emphasis on contextual competence, or that there was some emphasis, but the emphasis was inadequate. The same percentage of CHE respondents indicated that more emphasis should be placed on contextual competence in the humanities and social science courses taken by engineering students. Over one-third of the CHE respondents selected “other.” In each of these cases, the respondents provided comments explaining that they were unfamiliar with the content of humanities and social science courses taken by the chemical engineering students.

The HSS respondents were split in opinion on the adequacy of the level of emphasis placed on contextual competence in courses in the humanities and social sciences (50% selected “some emphasis, but inadequate” and 50% selected “some emphasis, and adequate” or “other”). A slightly larger proportion of the HSS respondents indicated that the level of emphasis should remain the same (57%), and 36% believed there should be more emphasis. The comments provide some insight into the HSS faculty responses. The main theme is integration of the content between courses in engineering and in the humanities and social sciences.

> I suspect there is inadequate integration of engineering with social science and humanities, but I haven't looked at this question directly.
>
> The H&SS courses should not be designed to appeal exclusively to engineering students (about 60% of the undergraduates) but faculty could be asked, encouraged, and assisted in using examples or cases that illustrate contextuality.
>
> Again [as in items 5a and 5b] the content is there, but needs to be refocused to apply more directly to professional work.

Another HSS respondent placed the burden of integration on the engineering faculty, stating that “engineering departments must take more responsibility for developing this area of competence.”

A majority of respondents from both groups of faculty selected logically consistent response combinations to items 6a and 6b (90% total for the CHE respondents, and 65% total for the HSS respondents, distributed among 4 different expected combinations). The most common mixed-response combination (“some emphasis, but inadequate” and “same,”) was selected by several respondents who commented on the need for integration of the content.

Research Question 4: Evaluating Contextual Competence

> How would faculty members in engineering and in the humanities and social sciences evaluate student achievement of contextual competence? When and where (e.g., in what courses) in the academic program would they evaluate student achievement?

Summaries of the responses from both groups of faculty on the types of evidence they would collect to evaluate student achievement on contextual competence, and the courses in which they would collect such evidence (items 2 and 3 of Questionnaire 1 respectively) are provided in Table 34 and Table 35.

Evidence of Student Achievement

Over half of the CHE respondents (55%) would evaluate student achievement in contextual competence through responses to technical problems that incorporate societal contextual factors. The technical problems would require students to

- explain complex societal concepts in writing;
- identify, evaluate and compare competing products or processes with respect to contextual factors;
- balance technical goals with societal goals; and
- justify their choices to the appropriate groups interested in the outcomes.

Students would be asked to demonstrate their achievement through written and oral reports on the results of capstone design projects and other open-ended projects. In these reports students would have to integrate the broader (societal) contextual factors into the analysis of alternatives, analyze and discuss of the sensitivity of alternatives to contextual factors, and justify their results and conclusions. A smaller proportion of CHE respondents (10%) would evaluate student achievement using essay-based discussions of case studies and societal contextual concepts as applied to problems and projects.

Over half of the HSS respondents (57%) would evaluate student achievement in contextual competence using papers, essays, and other written assignments in which students examine and critique case studies on ethical and social issues surrounding technology. Students would have to identify key factual, social and ethical issues of the case, and provide a reasoned argument in support of a well-crafted solution to a problem. Many HSS respondents (42%) would use in-class exercises, responses to qualitative and quantitative exam problems, and performance in class-room discussions and role-playing exercises. One respondent would use exit interviews in which students would be asked to give an example of contextual competence that she or he has gained from a course outside the major.

Suggested Courses for Collecting Evidence

Both CHE and HSS respondents identified capstone courses as a place for collecting evidence on student achievement in contextual competence. The CHE respondents (75%) identified the senior design course (Process Design and Economics, CHBE 4505), and the HSS respondents (21%) identified an interdisciplinary capstone course, project or exam. Interdisciplinary learning was a common thread in several responses. Respondents from both groups of faculty identified interdisciplinary courses or courses on science, technology and society (10% of CHE and 21% of HSS respondents). A small proportion of HSS respondents suggested engineering courses, modified to include humanities and social science content (21%).

CHE respondents (40%) recommended collecting evidence in all engineering courses, in exam questions, projects, problems in homework assignments, case study analyses, and class discussions. The HSS respondents (57%) would collect the same type of evidence in the humanities and social science courses taken by engineering students. A small proportion of HSS respondents would collect evidence in both engineering and humanities and social science courses (14%).

Other courses in which the respondents would collect evidence include humanities and social science courses focused on ethics, two upper-level chemical engineering courses (Process Safety, CHBE 4515, and unit operations courses), a first-year freshman seminar or the first-year chemical engineering courses (Chemical Process Principles, CHBE 2100), and undergraduate research.

Research Question 5: Effect of the Protocol

> What effect does participation in the protocol have on how engineering faculty define contextual competence? Does the protocol provide useful information for faculty members interested in academic program improvement?

The effect of the two-questionnaire protocol was explored by examining the change in the definition of contextual competence from Questionnaire 1 to Questionnaire 2 for each CHE respondent, and the nature of that change. The analysis also included faculty responses to two direct questions that asked if completion of the two questionnaires in the protocol changed their understanding and definition of the concept of contextual competence, and if they would use the results of the study in their undergraduate engineering program.

Change in the Definition

The change in the definition of contextual competence was defined as the difference between the number of outcome attributes selected in Questionnaire 2 and the number of outcome attributes identified in Questionnaire 1. The total number of outcome attributes identified in Questionnaire 1 and selected in Questionnaire 2 by each CHE respondent is displayed in Figure 2. The figure shows a dramatic increase in the number of outcome attributes used by the CHE respondents to define contextual competence from the first to the second questionnaire. The results of the two questionnaires, summarized in Table 36, show the following:

- The CHE respondents, on average, added 37 outcome attributes to the definition of contextual competence in the second questionnaire, increasing from an average of 5 to 42 outcome attributes.
- The definition of contextual competence provided in the second questionnaire by the CHE respondents included, on average, 24 of 34 outcome attributes identified only by engineering faculty in Questionnaire 1, 12 of 26 outcome attributes identified only by faculty in the humanities and social sciences, and 6 of 10 outcome attributes identified by faculty in both groups.

Table 37 shows the percentage of the 70 outcome attributes, distributed by source category, identified by the average CHE respondent in Questionnaire 1 and selected by the average CHE respondent in Questionnaire 2. The table shows that the CHE respondents, on average, defined contextual competence

- using only 7% of the 70 outcome attributes in Questionnaire 1.
- using 60% of the 70 outcome attributes to define contextual competence in Questionnaire 2.
- with 48% of the 26 outcome attributes that were included in the definition of contextual competence by respondents in the humanities and social sciences, but not by engineers, in Questionnaire 1.

Change in the Nature of the Definition

The nature of the change was defined as the difference in the distribution by source category of the outcome attributes identified in Questionnaire 1 and selected in Questionnaire 2 for the definition of contextual competence by the CHE respondents. Table 38 shows the distribution of the outcome attributes identified in Questionnaire 1 and selected in Questionnaire 2 by the CHE respondents, as a percentage of all attributes identified and selected, respectively. Table 38 also shows the number of attributes added by the CHE respondents to the definition of contextual competence from the pool of outcome attributes identified in Questionnaire 1 by engineering respondents only (34 of 70), humanities and social sciences respondents only (26 of 70), and by respondents in both engineering and the humanities and social sciences (10 of 70).

- The definition of contextual competence provided by the CHE respondents in Questionnaire 1 was composed of 84% outcome attributes identified by engineering respondents only and 16% outcome attributes identified by respondents in both faculty groups.
- The definition of contextual competence selected by the CHE respondents in Questionnaire 2 was composed of 57% attributes from engineering respondents only, 29% attributes from HSS respondents only, and 14% attributes identified by respondents from both groups of faculty.
- Of the attributes added to the definition of contextual competence by the CHE respondents from Questionnaire 1 to Questionnaire 2, 33% of the attributes were those identified in Questionnaire 1 by HSS respondents only and 53% were from engineering faculty only.

Effect of the Protocol

Eighty-two percent of the respondents reported that completion of the two questionnaires in the protocol changed their understanding and definition of the concept of contextual competence, and 88% indicated that they would use the results of the study in their undergraduate engineering program.

Table 13. Faculty Involvement in Discussions Regarding the Undergraduate Curriculum

Faculty Involvement	Level of Involvement in Discussions, % School	College	Institute	Total * Faculty Involved	Faculty Not Involved
Respondents who have served on a formal faculty curriculum committee that deliberated the humanities and social science courses taken by engineering students.					
CHE Faculty	30%	5%	5%	30%	70%
HSS Faculty	50%	21%	21%	57%	43%
Respondents who have participated in formal faculty discussions that deliberated the humanities and social science courses taken by engineering students.					
CHE Faculty	40%	10%	5%	40%	60%
HSS Faculty	29%	29%	36%	43%	57%

Note. * Some faculty have participated in committees or discussions at more than one level, therefore the total % of faculty involved is less than the sum of the % faculty reporting involvement at the different levels. CHE Faculty (N=20) and HSS Faculty (N=14).

Table 14. Interdisciplinary Activities Involving the Curriculum (CHE Faculty, N=20 and HSS Faculty, N=14).

Interdisciplinary Activities	Yes	No	No Response
Respondents who have taught an interdisciplinary course			
CHE Faculty	30%	70%	0%
HSS Faculty	7%	86%	7%
Participated as an investigator in an interdisciplinary research project involving the undergraduate engineering curriculum			
CHE Faculty	10%	90%	0%
HSS Faculty	29%	64%	7%

Table 15. Discussions about Multidisciplinary Outcomes (CHE Faculty, N=20 and HSS Faculty, N=14).

Involvement in Discussions		Yes	No	No Response
Participated in <u>discussions with colleagues about the contextual competence outcome (h)</u> and how students develop it.				
	CHE Faculty	60%	40%	0%
	HSS Faculty	57%	36%	7%
Participated in <u>discussions with engineering faculty</u> regarding the socio-humanistic objectives of an engineering course (humanities and social science faculty only)				
	HSS Faculty	21%	72%	7%
Participated on an <u>external program review committee for ABET</u> (engineering faculty only)				
	CHE Faculty	10%	90%	0%
Participated on an <u>internal review committee or self-study committee</u> (engineering faculty only)				
	CHE Faculty	40%	55%	5%

Table 16. Distribution of Contacts, by Discipline and Institutional Affiliation, Whom the Respondents Would Seek for Information about Contextual Competence

	Contacts Identified by: CHE Respondents	Contacts Identified by: HSS Respondents
Total Number of Contacts	39	34
Percentage of Contacts		
In Engineering	90%	26%
In Humanities and Social Sciences	5%	71%
In Other Disciplines	5%	3%
Located at Georgia Tech	49%	74%
Located at Other Institutions	51%	26%
At Georgia Tech in Engineering	46%	18%
At Georgia Tech in Humanities and Social Sciences	3%	56%
At Georgia Tech in Other Disciplines	0%	0%

Table 17. Proportion of Respondents Identifying Contacts in Their Own and in Other Disciplines, at Georgia Tech and at Other Institutions

		Chemical Engineering Faculty	Humanities and Social Sciences Faculty
Number of Respondents Who Identified Contacts		15	12
Percentage of Respondents Who Identified:			
At Least One Contact in Own Faculty Group at Georgia Tech (%)		60%	75%
Identified at Least One Contact in:	Engineering	100%	58%
	Humanities and Social Sciences	13%	92%
	Other Disciplines	13%	8%
Identified Contacts Only in:	Engineering	73%	0%
	Humanities and Social Sciences	0%	42%
	Other Disciplines	0%	0%
Identified Contacts Located Only at Other Institutions		33%	8%

Table 18. Themes Used to Code CHE and HSS Definitions of Contextual Competence (Questionnaire 1, Item 1)

Themes	Sub-themes	Topics Identified in Definitions of Contextual Competence
Technology and Society	Social considerations, general	Social or societal viewpoint, real world, sociocultural whole; affected individuals or groups, institutions, community; societal or social factors, effects, impacts, benefits, detriments, issues, tangible and intangible implications; quality of life, well-being, or human condition, or other sociological or political criteria, politics
	Needs	Needs, demands, technological needs
	Impact of technology on society	Impact or influence of technology on culture or humanity; impact of the engineering profession on society, the engineer's role in society, or engineering as sociological or political undertaking
	Impact of society on technology	Impact or influence of societal needs, influence of public policy or politics on technology, design of technology, adaptation or changes in technology;
	Historical perspectives	Historical perspectives on technological development, case studies; history, historical issues
	Arts and literature	Arts, literature
Diverse Cultures and Values	Considerations of diversity	Diversity or diverse populations, contextual complexity, or multiple perspectives; intercultural and international differences; popular press accounts of world; democratic and non-democratic forms of government, liberal democracy; foreign language
	Global impacts	Global impacts or effects explicitly mentioned
Engineering Practice and Decision Making in Context	Technical considerations	Technical or scientific viewpoint; chemical products, processes, specifications or technical materials; factual knowledge of engineering, fundamental skills, framework and analysis tools, scale and application of engineering, assumptions for, need for, and/or calculations for technical design
	Environmental considerations	Environmental viewpoint, biosphere, natural resources or general environmental knowledge and awareness; environmental quality, effects, impacts, wastes, pollutants, or detrimental consequences on environment; environmental management, impact studies, maintenance, stewardship; or otherwise not specified; sustainability or sustainable engineering, energy efficiency
	Communication	Communication and documentation of engineering process or results; writing, essays, reading scholarly texts, leadership, teamwork
	Decision making skills	Balance, weigh, compare and contrast, assess tradeoffs; acceptability of technological solutions; sensitivity analysis; strategic planning , logic

Themes	Sub-themes	Topics Identified in Definitions of Contextual Competence
Economics	Economic considerations	Economic viewpoint, economic impacts, or costs; profitability or economic feasibility; resource management, use, allocation, distribution, redistribution, resource scarcity; economic dimensions or modes of thought; economic social forces
	Macroeconomic perspective	Global economy, global economics or global economic contextual variable
	Microeconomic perspective	Business context or situation, business partners, commercial enterprise, commercialization of technology, business proposals, economic decisions of the firm, outsourcing of off-shore manufacturing
Safety	Safety considerations	Safety aspects, public safety, safety impacts, risks to safety, inherent risks; process or plant/facility safety, safety systems, protocols or procedures, product safety, design and/or use of safe products; use of toxic materials, persistent (in the biosphere) materials, or threatening agents; risk assessment, hazard analysis
Human Behavior and Technology	Human behavior and values	Human behavior, values, beliefs or attitudes; ideologies or theories of behavior; human culture; human factors; use of technology by humans
Ethics	Ethical considerations	Ethical considerations in solutions to problems, judgments or decisions; ethical reasoning; ethical perspectives, dimensions or modes of thought; ethical knowledge; future generations
	Codes of professional practice	Codes of ethical or responsible professional behavior, recognition of unethical behavior, extended responsibility (from design to use); due diligence, balancing expedience vs. due diligence; ethical situations, implications of relationships with others in the workplace; ethical fortitude; good citizens

Table 19. Number of Outcome Attributes for Contextual Competence Identified by Respondents Cross Tabulated by Theme and by Source of Contribution

Theme	Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents	Total
Technology and Society	4	1	4	9
Diverse Cultures and Values	0	10	1	11
Engineering Practice and Decision Making in Context	12	6	2	20
Economics and Business	4	2	3	9
Safety	7	0	0	7
Human Behavior and Technology	1	3	0	4
Ethics and the Engineering Profession	6	4	0	10
Total	34	26	10	70

Table 20. Outcome Attributes Organized by Theme (Results of Questionnaire 1, item 1)

Used for Questionnaire 2 Item #	Outcome Attribute Statement (N=70) Students should be able to . . .	Source Category		
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents
	Technology and society.			
1a	Know, identify, describe and analyze the major domestic and foreign historical, political, cultural, economic and social forces that confront and define the United States and other countries of the world, and understand the role such forces play in technology development and the engineering profession.			x
1b	Describe and discuss how technological change impacts the way society and its structures evolve.			x
1c	Appreciate history, politics, literature, and the arts, what they tell us about the human condition, and how they complement technology.			x
1d	Demonstrate an interest in actively learning about the history behind a technology and its ethical and societal implications.	x		
1e	Identify the current and future technological trends and needs of society, in particular those that will have a major impact on our culture and society.	x		
1f	Understand issues of sustainability and the impact of professional engineering work on the production of global, societal well-being (in terms of economic, ethical and environmental quality) and quality of life (in terms of convenience, health, environment, safety, and the economy).	x		
1g	Deliver a thoughtful seminar on the broader societal context of a technology.	x		
1h	Read critically and discuss scholarly texts both orally and in writing. They should practice and use reading and writing skills, and be able to write clear, critical or analytical papers on a wide range of subjects.		x	
1i	Apply insights about engineering-in-social-context to their own career choices and professional practice with the understanding that engineering is necessarily a social and political undertaking.			x
	Diverse cultures and values.			
2a	Recognize intercultural and international differences and understand that other people will have different attitudes, beliefs, lifestyles and values than themselves.		x	
2b	Understand that cultural and national perspectives are complex and often in competition with each other.		x	

Used for Questionnaire 2 Item #	Outcome Attribute Statement (N=70) Students should be able to . . .	Source Category		
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents
2c	Understand the social and cultural values that are *embodied in* engineering design and practices, including how engineering practices depend on assumptions about the characteristics of users (e.g., their education, attitudes, wealth, goals) and their societies (e.g., how economic or political processes will put a technology into practice).		x	
2d	Understand the importance of diversity and how diverse populations will be affected by the engineered world around them.		x	
2e	Appreciate and respect the importance of multiple perspectives and enjoy debating with individuals that express different perspectives in frank discussions.			x
2f	Speak a foreign language, or at least be competent in a foreign language in social situations.		x	
2g	Understand the intellectual foundations upon which the American Republic was built.		x	
2h	Differentiate, compare, and analyze differences between the American form of liberal democracy and other democratic and non-democratic forms of government.		x	
2i	Critically read and understand popular press accounts about the world around them.		x	
2j	Write critical essays on social issues so as to demonstrate an ability to mobilize fact and opinion surrounding a controversial issue.		x	
2k	Muster evidence to substantiate opinion, and recognize the difference between indoctrinated opinion and assessments based on evidence and fact.		x	
	Engineering practice and decision making in context.			
3a	Complete basic calculations in chemical engineering and observe when proposed engineering solutions are technically infeasible or impractical.	x		
3b	Evaluate the impacts of engineering solutions to a range of problems of different scales and applications areas.	x		
	Identify, assess and evaluate both qualitative and quantitative impacts of products and processes, including:			
3c	Economic impact and commercialization potential	x		
3d	Ethical issues	x		
3e	Safety issues	x		
3f	Environmental effects, energy efficiency, resource utilization, sustainability	x		

Used for Questionnaire 2 Item #	Outcome Attribute Statement (N=70) Students should be able to . . .	Source Category: Engineering Respondents Only	Source Category: Humanities and Social Sciences Respondents Only	Source Category: Both Engineering and HSS Respondents
3g	Competing interests and values at stake in a project, including those which are not necessarily voiced			x
3h	Optimize a design using the important contextual variables in the design variable set.	x		
3i	Predict the range of possibilities that an engineering solution could have within a global and societal context.		x	
3j	Weigh the desired engineering results against the interests and needs of a larger community, and find a balance among costs and benefits that cannot necessarily be expressed in numerical formulas.			x
3k	Justify and clearly document the tradeoffs they have made in reaching their design and to argue their case.	x		
3l	Defend or challenge a proposed engineering solution based upon a broad and deep assessment of the needs and claims of all parties involved.		x	
3m	Explain the sociological assumptions that were used to arrive at their engineering decisions, and give examples of how different sociological assumptions would lead to different decisions.	x		
3n	Revisit the assumptions behind their engineering solutions and change or modify their choices when presented with new evidence for the global and societal impacts of their decisions.	x		
3o	Model the outcomes of changes in engineering solutions made in response to new evidence of global and societal impacts, and synthesize new solutions.	x		
3p	Effectively communicate engineering decisions, concerns and observations to appropriate individuals and groups.	x		
3q	Know and comprehend the basic steps toward strategic planning and decision making, as well as the rules of logic.		x	
	Demonstrate decision making skills where they			
3r	Effectively synthesize and analyze knowledge and apply it to a decision context.		x	
3s	Evaluate the outcomes of their decision.		x	
3t	Implement their decisions on an individual basis and by working in groups in both face-to-face and electronic group contexts.		x	

Used for Questionnaire 2 Item #	Outcome Attribute Statement (N=70) Students should be able to . . .	Source Category Engineering Respondents Only	 Humanities and Social Sciences Respondents Only	 Both Engineering and HSS Respondents
	Economics and business			
4a	Know and understand micro- and macroeconomics, how economists approach decision making, and how decisions made in the technology arena play out in the economic environment of a firm or organization and in the global economy.			x
4b	Analyze, from an economist's mind set, macro policy issues at the national/regional level, economic decisions made at the firm level, and economic impacts of proposed engineering solutions (including performance of risk assessment and cost-benefit analyses).			x
4c	Assess the societal benefits and detriments associated with outsourcing and offshore manufacturing.	x		
4d	Demonstrate comprehension of redistribution of resources, allocation of scarce resources, and cultural impacts resulting from engineering projects.	x		
4e	Properly allocate scarce resources and determine price quantity combinations that ensure the viability of the organization and meet the demands of society.			x
4f	Judge engineering solutions to a given problem in a context where economic and business, sociological, historical, ethical, environmental and political criteria are at least as important as the science and engineering criteria.	x		
4g	Anticipate how social forces (economic and business, sociological, historical, ethical, environmental and political) will affect the implementation, success, and acceptance of engineering solutions.		x	
4h	Judge whether or not engineering solutions should be introduced, recalled, or otherwise adapted.	x		
4i	Respect intercultural and international differences in dealing with business partners. They should be able to generate business proposals and evaluate business situations based on background knowledge of such differences.		x	
	Safety			
5a	Assess the risks and safety issues associated with any chemical process, product, or facility in the broader societal context, and raise the safety issues as questions for discussion.	x		
5b	Discuss the concept of "inherent risk".	x		
5c	Assess the balance between the need for public safety and the need for the new technology.	x		
5d	Recognize toxic or ecologically persistent materials if these are involved in a proposed process, and be able to predict if such materials are likely to be formed under the proposed conditions	x		

Used for Questionnaire 2 Item #	Outcome Attribute Statement (N=70) Students should be able to . . .	Source Category		
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents
5e	Design or synthesize an appropriate safety or containment system for any chemical process or product.	x		
5f	Assess safe protocols and write these protocols into the procedures that will be used by personnel who are working with the process equipment.	x		
5g	Explain the role of the engineer in public safety at multiple levels: worker and personal safety; local community safety; societal safety.	x		
	Human behavior and technology			
6a	Discriminate among competing theories, explanations, and ideologies for human behavior and culture, and be able to describe competing explanations for social behavior.		x	
6b	Challenge their own beliefs about human behavior and the values, beliefs, and attitudes that may underlie that behavior.		x	
6c	Identify the “human factors” (e.g., human psychology, human errors or imperfection, uncertainties created by human and their interactions, and communication) involved in development of an engineering solution.	x		
6d	Assess the impact of human factors on the effectiveness of an engineering solution, and the ability of people to make use of the solution.		x	
	Ethics and the engineering profession			
7a	Recognize their role as "good citizens" in society and understand the accompanying responsibilities and duties.	x		
7b	Work as responsible professionals, actively acquiring specific technical knowledge about the aspects of the chemical engineering profession that are most likely to directly impact society.	x		
7c	Articulate the fundamental principles of ethical reasoning.		x	
7d	Evaluate science and technology based activities and outcomes from ethical perspectives.		x	
7e	Analyze and evaluate historical and/or hypothetical case studies, indicating what they might do in a given situation and why.		x	
7f	Understand the need for ethical professional behavior, exhibit critical thinking when presented with an ethical situation, and be willing to make engineering judgments and decisions that are ethically correct and consistent with accepted professional practice.	x		

Used for Questionnaire 2 Item #	Outcome Attribute Statement (N=70) Students should be able to . . .	Source Category		
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents
7g	Comprehend the basic factors associated with sound leadership and ethical behavior and be able to differentiate between leadership and management.		x	
	Distinguish ethical and social considerations from matters of expediency or self interest. They should be able to			
7h	Assess the relative merits of expedience and exercise due diligence.	x		
7i	Defend a position on the side of due diligence even when this position may be contrary to the wishes of his/her superiors.	x		
7j	Resolutely and passionately support engineering solutions that are fundamentally correct and socially beneficial, even if such solutions are not politically popular.	x		
	Total Number of Outcome Attributes	34	26	10

Table 21. Number of Outcome Attributes Selected by a Majority of the CHE Respondents, Cross Tabulated by Response Category and Source Category

Response Categories	Total	Source Category		
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents
Desirable and Included in the Definition of Contextual Competence	44	26	12	6
Included in the Definition and Should Be Evaluated and Included in ABET Self-Study*	21	15	6	0
Desirable, but Not Included in Definition of Contextual Competence	16	3	10	3
Not Selected by a Majority of Respondents in Any Category	10	5	4	1
Total	70	34	26	10

Note. * The outcome attributes selected in this category are a subset of the 44 attributes that were selected as desirable and included in the definition of contextual competence.

Table 22. Outcome Attributes Included in the Definition of Contextual Competence by a Majority of CHE Respondents, Identified by Source Category and by Selection for Evaluation and Incorporation in ABET Self-Study

Questionnaire 2 Item #	Outcome Attribute Statement (N=44) Students should be able to	Source Category			Evaluate and Include in ABET Self-Study (Shaded)
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents	
	Technology and society.				
1a	Know, identify, describe and analyze the major domestic and foreign historical, political, cultural, economic and social forces that confront and define the United States and other countries of the world, and understand the role such forces play in technology development and the engineering profession.			x	
1b	Describe and discuss how technological change impacts the way society and its structures evolve.			x	
1e	Identify the current and future technological trends and needs of society, in particular those that will have a major impact on our culture and society.	x			
1f	Understand issues of sustainability and the impact of professional engineering work on the production of global, societal well-being (in terms of economic, ethical and environmental quality) and quality of life (in terms of convenience, health, environment, safety, and the economy).	x			x
1h	Read critically and discuss scholarly texts both orally and in writing. They should practice and use reading and writing skills, and be able to write clear, critical or analytical papers on a wide range of subjects.		x		x
1i	Apply insights about engineering-in-social-context to their own career choices and professional practice with the understanding that engineering is necessarily a social and political undertaking.			x	
	Diverse cultures and values.				
2c	Understand the social and cultural values that are *embodied in* engineering design and practices, including how engineering practices depend on assumptions about the characteristics of users (e.g., their education, attitudes, wealth, goals) and their societies (e.g., how economic or political processes will put a technology into practice).		x		

Questionnaire 2 Item #	Outcome Attribute Statement (N=44) Students should be able to	Source Category			Evaluate and Include in ABET Self-Study (Shaded)
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents	
	Engineering practice and decision making in context.				
3a	Complete basic calculations in chemical engineering and observe when proposed engineering solutions are technically infeasible or impractical.	x			x
3b	Evaluate the impacts of engineering solutions to a range of problems of different scales and applications areas.	x			x
	Identify, assess and evaluate both qualitative and quantitative impacts of products and processes, including:				
3c	Economic impact and commercialization potential	x			x
3d	Ethical issues	x			x
3e	Safety issues	x			x
3f	Environmental effects, energy efficiency, resource utilization, sustainability	x			x
3g	Competing interests and values at stake in a project, including those which are not necessarily voiced			x	
3h	Optimize a design using the important contextual variables in the design variable set.	x			x
3i	Predict the range of possibilities that an engineering solution could have within a global and societal context.		x		
3j	Weigh the desired engineering results against the interests and needs of a larger community, and find a balance among costs and benefits that cannot necessarily be expressed in numerical formulas.			x	
3k	Justify and clearly document the tradeoffs they have made in reaching their design and to argue their case.	x			x
3l	Defend or challenge a proposed engineering solution based upon a broad and deep assessment of the needs and claims of all parties involved.		x		x
3n	Revisit the assumptions behind their engineering solutions and change or modify their choices when presented with new evidence for the global and societal impacts of their decisions.	x			
3o	Model the outcomes of changes in engineering solutions made in response to new evidence of global and societal impacts, and synthesize new solutions.	x			

Questionnaire 2 Item #	Outcome Attribute Statement (N=44) Students should be able to	Source Category			Evaluate and Include in ABET Self-Study (Shaded)
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents	
3p	Effectively communicate engineering decisions, concerns and observations to appropriate individuals and groups.	x			x
3q	Know and comprehend the basic steps toward strategic planning and decision making, as well as the rules of logic.		x		x
	Demonstrate decision making skills where they				
3r	Effectively synthesize and analyze knowledge and apply it to a decision context.		x		x
3s	Evaluate the outcomes of their decision.		x		x
3t	Implement their decisions on an individual basis and by working in groups in both face-to-face and electronic group contexts.		x		x
	Economics and business				
4a	Know and understand micro- and macroeconomics, how economists approach decision making, and how decisions made in the technology arena play out in the economic environment of a firm or organization and in the global economy.			x	
4d	Demonstrate comprehension of redistribution of resources, allocation of scarce resources, and cultural impacts resulting from engineering projects.	x			
4f	Judge engineering solutions to a given problem in a context where economic and business, sociological, historical, ethical, environmental and political criteria are at least as important as the science and engineering criteria.	x			
4g	Anticipate how social forces (economic and business, sociological, historical, ethical, environmental and political) will affect the implementation, success, and acceptance of engineering solutions.		x		
4h	Judge whether or not engineering solutions should be introduced, recalled, or otherwise adapted.	x			
	Safety				
5a	Assess the risks and safety issues associated with any chemical process, product, or facility in the broader societal context, and raise the safety issues as questions for discussion.	x			x
5b	Discuss the concept of "inherent risk".	x			x

Questionnaire 2 Item #	Outcome Attribute Statement (N=44) Students should be able to	Source Category			Evaluate and Include in ABET Self-Study (Shaded)
		Engineering Respondents Only	Humanities and Social Sciences Respondents Only	Both Engineering and HSS Respondents	
5c	Assess the balance between the need for public safety and the need for the new technology.	x			
5d	Recognize toxic or ecologically persistent materials if these are involved in a proposed process, and be able to predict if such materials are likely to be formed under the proposed conditions	x			x
5e	Design or synthesize an appropriate safety or containment system for any chemical process or product.	x			x
5f	Assess safe protocols and write these protocols into the procedures that will be used by personnel who are working with the process equipment.	x			x
5g	Explain the role of the engineer in public safety at multiple levels: worker and personal safety; local community safety; societal safety.	x			
	Ethics and the engineering profession				
7a	Recognize their role as "good citizens" in society and understand the accompanying responsibilities and duties.	x			
7b	Work as responsible professionals, actively acquiring specific technical knowledge about the aspects of the chemical engineering profession that are most likely to directly impact society.	x			
7c	Articulate the fundamental principles of ethical reasoning.		x		
7d	Evaluate science and technology based activities and outcomes from ethical perspectives.		x		
7e	Analyze and evaluate historical and/or hypothetical case studies, indicating what they might do in a given situation and why.		x		
7f	Understand the need for ethical professional behavior, exhibit critical thinking when presented with an ethical situation, and be willing to make engineering judgments and decisions that are ethically correct and consistent with accepted professional practice.	x			
	Total Number of Outcome Attributes	26	12	6	21

Table 23. Outcome Attributes Selected by a Majority of CHE Respondents as Desirable, but Not for the Definition of Contextual Competence

Questionnaire 2 Item #	Outcome Attribute Statement (N=16) Students should be able to	Source Category		
		Engineering Respondents Only	HSS Respondents Only	Both Engineering and HSS Respondents
	Technology and society.			
1c	Appreciate history, politics, literature, and the arts, what they tell us about the human condition, and how they complement technology.			x
1d	Demonstrate an interest in actively learning about the history behind a technology and its ethical and societal implications.	x		
	Diverse cultures and values.			
2a	Recognize intercultural and international differences and understand that other people will have different attitudes, beliefs, lifestyles and values than themselves.		x	
2b	Understand that cultural and national perspectives are complex and often in competition with each other.		x	
2d	Understand the importance of diversity and how diverse populations will be affected by the engineered world around them.		x	
2e	Appreciate and respect the importance of multiple perspectives and enjoy debating with individuals that express different perspectives in frank discussions.			x
2g	Understand the intellectual foundations upon which the American Republic was built.		x	
2h	Differentiate, compare, and analyze differences between the American form of liberal democracy and other democratic and non-democratic forms of government.		x	
2i	Critically read and understand popular press accounts about the world around them.		x	
	Engineering practice and decision making in context.			
3m	Explain the sociological assumptions that were used to arrive at their engineering decisions, and give examples of how different sociological assumptions would lead to different decisions.	x		

Questionnaire 2 Item #	Outcome Attribute Statement (N=16) Students should be able to	Source Category		
		Engineering Respondents Only	HSS Respondents Only	Both Engineering and HSS Respondents
	Economics and business			
4b	Analyze, from an economist's mind set, macro policy issues at the national/regional level, economic decisions made at the firm level, and economic impacts of proposed engineering solutions (including performance of risk assessment and cost-benefit analyses).			x
4i	Respect intercultural and international differences in dealing with business partners. They should be able to generate business proposals and evaluate business situations based on background knowledge of such differences.		x	
	Human behavior and technology			
6a	Discriminate among competing theories, explanations, and ideologies for human behavior and culture, and be able to describe competing explanations for social behavior.		x	
6b	Challenge their own beliefs about human behavior and the values, beliefs, and attitudes that may underlie that behavior.		x	
6d	Assess the impact of human factors on the effectiveness of an engineering solution, and the ability of people to make use of the solution.		x	
	Ethics and the engineering profession Distinguish ethical and social considerations from matters of expediency or self interest. They should be able to			
7i	Defend a position on the side of due diligence even when this position may be contrary to the wishes of his/her superiors.	x		
	Total Number of Outcome Attributes	3	10	3

Table 24. Outcome Attributes Not Selected by a Majority of Respondents in Any Response Category

Questionnaire 2 Item #	Outcome Attribute Statement (N=10) Students should be able to	Source Category: ENG Only	Source Category: HSS Only	Source Category: Both ENG and HSS	Selected as Desirable: Included in Definition of Contextual Competence %	Selected as Desirable: Not Included in Definition of Contextual Competence %
	Technology and society.					
1g	Deliver a thoughtful seminar on the broader societal context of a technology.	x			41	41
	Diverse cultures and values.					
2f	Speak a foreign language, or at least be competent in a foreign language in social situations.		x		24	47
2j	Write critical essays on social issues so as to demonstrate an ability to mobilize fact and opinion surrounding a controversial issue.		x		35	41
2k	Muster evidence to substantiate opinion, and recognize the difference between indoctrinated opinion and assessments based on evidence and fact.		x		47	47
	Economics and business					
4c	Assess the societal benefits and detriments associated with outsourcing and offshore manufacturing.	x			35	47
4e	Properly allocate scarce resources and determine price quantity combinations that ensure the viability of the organization and meet the demands of society.			x	41	47
	Human behavior and technology					
6c	Identify the "human factors" (e.g., human psychology, human errors or imperfection, uncertainties created by human and their interactions, and communication) involved in development of an engineering solution.	x			41	41
	Ethics and the engineering profession					
7g	Comprehend the basic factors associated with sound leadership and ethical behavior and be able to differentiate between leadership and management.		x		47	35
	Distinguish ethical and social considerations from matters of expediency or self interest. They should be able to					
7h	Assess the relative merits of expedience and exercise due diligence.	x			41	41
7j	Resolutely and passionately support engineering solutions that are fundamentally correct and socially beneficial, even if such solutions are not politically popular.	x			41	47
	Total Number of Outcome Attributes	5	4	1		

Table 25. Faculty Opinions on How Students Would Best Develop Contextual Competence in Courses in the Undergraduate Curriculum

Through coursework in	Chemical Engineering Faculty (N=20)	Humanities and Social Sciences Faculty (N=14)
Engineering	0%	0%
Both engineering and the humanities and social sciences, but primarily engineering	75%	22%
Both engineering and the humanities and social sciences, but primarily humanities and social sciences	10%	43%
Humanities and social sciences	5%	14%
Not developed through coursework	0%	0%
Other	10%	21%

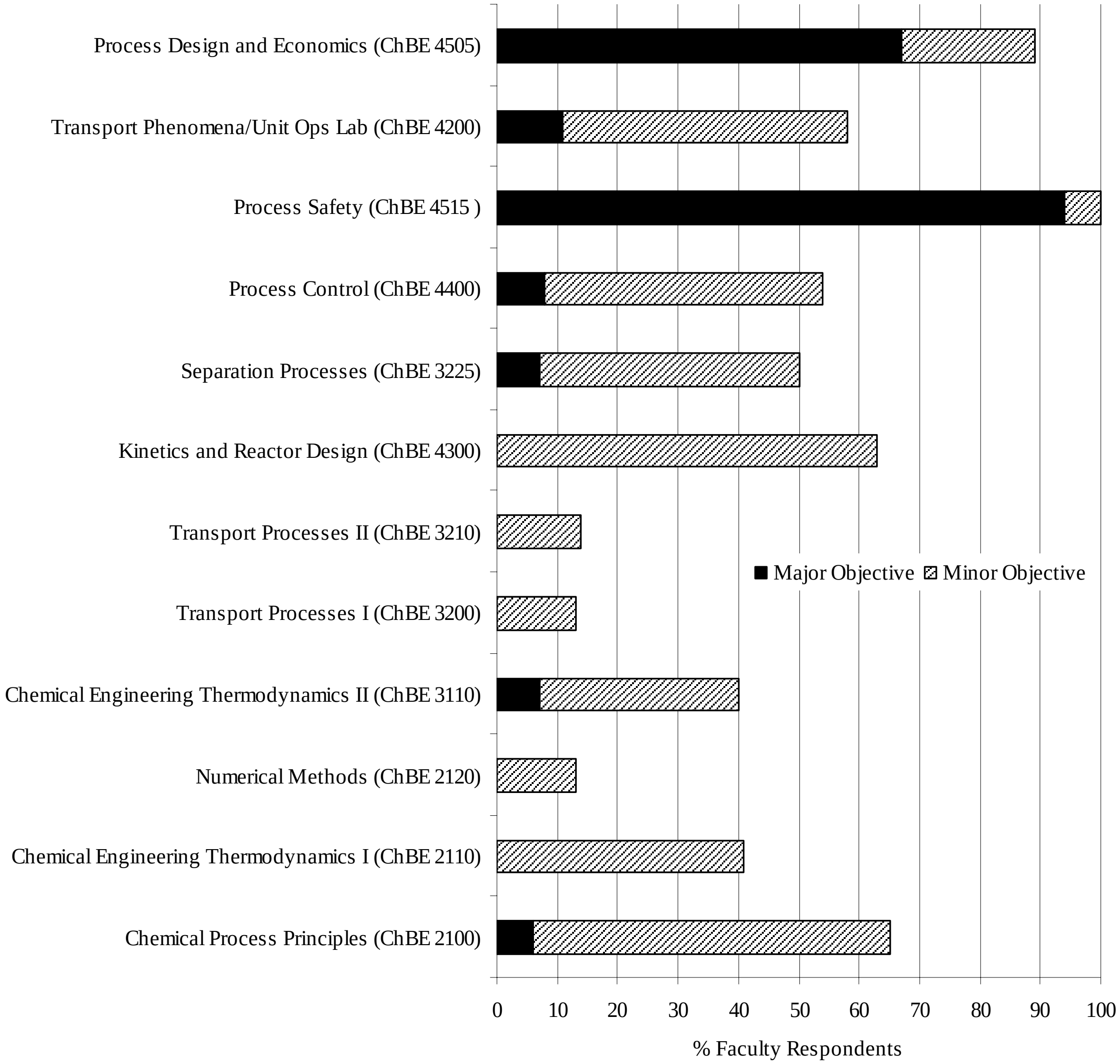

Figure 1. Contextual Competence as a Major or Minor Objective in Core Chemical Engineering Courses, as a Percentage of CHE Respondents Indicating Familiarity with the Course

Table 26. Comparison of CHE Faculty Ratings of the Emphasis Placed on Contextual Competence in Required Chemical Engineering Courses, Based on Experience Teaching the Course

Course Name		Respondents Who have Not Taught the Course			
	Rating by Respondents Who Have Taught the Course	Most Common Rating	Respondents Rating the Course, N	Variation Ratio, %	Perception Compared to Respondents Who Taught the Course
Chemical Process Principles	Minor	Minor	11	36	Same Level of Emphasis
Chemical Eng. Thermodynamics I	Minor	Informal	14	43	Less Emphasis
Numerical Methods	Informal	Not an Objective	10	40	Less Emphasis
Chemical Eng. Thermodynamics II	Minor	Informal	10	20	Less Emphasis
Transport Processes I	Not an Objective	Informal	12	17	More Emphasis
Transport Processes II	Informal	Informal	12	33	Same Level of Emphasis
Kinetics and Reactor Design	Minor	Minor	13	38	Same Level of Emphasis
Separation Processes	Informal to Minor	Informal to Minor	10	50	Same Level of Emphasis
Process Control	Informal	Minor	8	50	More Emphasis
Process Safety	Major	Major	15	7	Same Level of Emphasis
Transport Phenomena/Unit Ops Lab	Minor	Informal	13	53	Less Emphasis
Process Design and Economics	Major	Major	16	31	Same Level of Emphasis

Table 27. Humanities and Social Science Courses in which Contextual Competence is a Major Objective, as Identified by Humanities and Social Sciences Faculty (N=14)

Subject	Course Title	Course Number
Economics	Economics and Policy	ECON 2100
	Principles of Microeconomics	ECON 2106
	Industrial Organization	ECON 4340
	Economic Regulation	ECON 4345
	Environmental Economics	ECON 4440
History, Technology, and Society	Engineering in History	HTS 1081
	Technology and Society	HTS 2084
	Technology and Shaping of American Society	HTS 3083
International Affairs	American Government in Comparative Perspective	INTA 1200
	Ethics and International Affairs	INTA 2030
Literature, Communication and Culture	Science, Technology, and American Empire	LCC 2118
	Science, Technology and Post-Colonialism	LCC 3316
	Biomedicine and Culture	LCC 3318
Modern Languages	All languages at 2000 level and above	
	All languages: business	
	All languages: technology/science	
Philosophy of Science and Technology	Ethical Theory	PST 3105
	Ethics in the Technical Professions	PST 3109
	Science, Technology and Human Values	PST 3127
Psychology	General Psychology	PSY 1101
	Developmental Psychology	PSY 2103
	Social Psychology	PSY 2210
	Abnormal Psychology	PSY 2230
	Personality Psychology	PSY 2240
Public Policy	Sustainability, Technology, and Policy	PUBP 3600
	Environmental Policy and Regulation	PUBP 4314
	Environmental Impact Assessment	PUBP 4338

Table 28. Humanities and Social Science Courses in which Contextual Competence is a Minor Objective, as Identified by Humanities and Social Sciences Faculty (N=14),

Subject	Course Title	Course Number
Economics	Principles of Macroeconomics	ECON 2105
	Empirical Economics	ECON 3160
International Affairs	International Relations	INTA 1110
	American Foreign Policy	INTA 3110
	Great Power Relations	INTA 2100
Literature, Communication and Culture	Introduction to Science, Technology and Culture	LCC 2100
	Science, Technology and Gender	LCC 3304
	Science, Technology and Race	LCC 3306
	Environmentalism and Ecocriticism	LCC 3308
Philosophy of Science and Technology	Environmental Ethics	PST 4176
Psychology	Research Methods in Psychology	PSY 2010
	Comparative Psychology	PSY 3060
	Applied Experimental Psychology	PSY 4031
Public Policy	Science, Technology, and Public Policy	PUBP 4410

Table 29. Humanities and Social Science Courses in which Contextual Competence is Addressed Informally, as Identified by Humanities and Social Sciences Faculty (N=14),

Subject	Course Title	Course Number
History, Technology, and Society	Sociology of Race and Ethnicity	HTS 3026
International Affairs	Science, Technology and International Affairs	INTA 2040
Literature, Communication and Culture	Science, Technology and Ideology	LCC 3302
Philosophy of Science and Technology	Modern Philosophy	PST 3103
	Science and Values in the Policy Process	PST 2068
Psychology	Industrial and Organizational Psychology	PSY 2220
	Engineering Psychology	PSY 2270
Public Policy	Social Policy	PUBP 3201
	Social Policy	PUBP 4200
	Foundations and Public Policy	PUBP 2012
	Policy Analysis and Program Evaluation	PUBP 4130

Table 30. Faculty Opinion of the Overall Level of Emphasis on the Development of Contextual Competence in the Required Undergraduate Chemical Engineering Courses

Level of Emphasis *is*	Chemical Engineering Faculty (N=20)	Humanities and Social Sciences Faculty (N=14)
No Emphasis	0%	0%
Some Emphasis, but Inadequate	60%	43%
Some Emphasis, and Adequate	35%	36%
Too Much Emphasis	0%	7%
Other	5%	14%

Table 31. Faculty Opinion of What the Overall Level of Emphasis on the Development of Contextual Competence in the Required Undergraduate Chemical Engineering Courses Should Be

Level of Emphasis *should be*	Chemical Engineering Faculty (N=20)	Humanities and Social Sciences Faculty (N=14)
Less	0%	0%
Same	15%	57%
More	75%	43%
No Opinion	10%	0%

Table 32. Faculty Opinion of the Overall Level of Emphasis on the Development of Contextual Competence in the Courses in the Humanities and Social Sciences Taken by Engineering Students

Level of Emphasis *is*	Chemical Engineering Faculty (N=20)	Humanities and Social Sciences Faculty (N=14)
No Emphasis	20%	0%
Some Emphasis, but Inadequate	35%	50%
Some Emphasis, and Adequate	10%	43%
Too Much Emphasis	0%	0%
Other	35%	7%

Table 33. Faculty Opinion on What the Overall Level of Emphasis on the Development of Contextual Competence in the Courses in the Humanities and Social sciences Taken by Engineering Students Should Be

Level of Emphasis *should be*	Chemical Engineering Faculty (N=20)	Humanities and Social Sciences Faculty (N=14)
Less	0%	0%
Same	15%	57%
More	55%	36%
No Opinion	30%	7%

Table 34. Types of Evidence the Chemical Engineering Respondents Would Collect to Evaluate Contextual Competency

Types of evidence	Percentage of Chemical Engineering Faculty Who Identified Each Response (N=20)
Responses to technical problems that incorporate broader (societal) contextual factors and require students to explain complex societal concepts in writing; identify, evaluate and compare competing products or processes with respect to contextual factors; balance technical goals with societal goals; and justify choices.	55%
Reports (written and oral) on the results of capstone design or open-ended projects, including: integration of broader, (societal) contextual factors in alternatives, analysis of the sensitivity of alternatives to contextual factors, and justification of results and conclusions.	50%
Essay-based discussions of case studies and broader, (societal) contextual concepts as applied to problems and projects.	10%

Table 35: Types of Evidence the Humanities and Social Science Respondents Would Collect to Evaluate Contextual Competency

Types of evidence	Percentage of Humanities and Social Sciences Faculty Who Identified Each Response (N=14)
Papers, essays, and other written assignments in which students examine and critique case studies on ethical and social issues surrounding technology' identify key factual, social and ethical issues of the case, and provide a reasoned argument in support of a well-crafted solution to a case.	57%
In-class exercises, including responses to qualitative and quantitative exam problems, and performance in class-room discussions and role-playing exercises.	42%
Exit interviews in which students explain some example of contextual competency that she or he has gained from a course outside the major.	7%
Ability to speak a foreign language.	7%

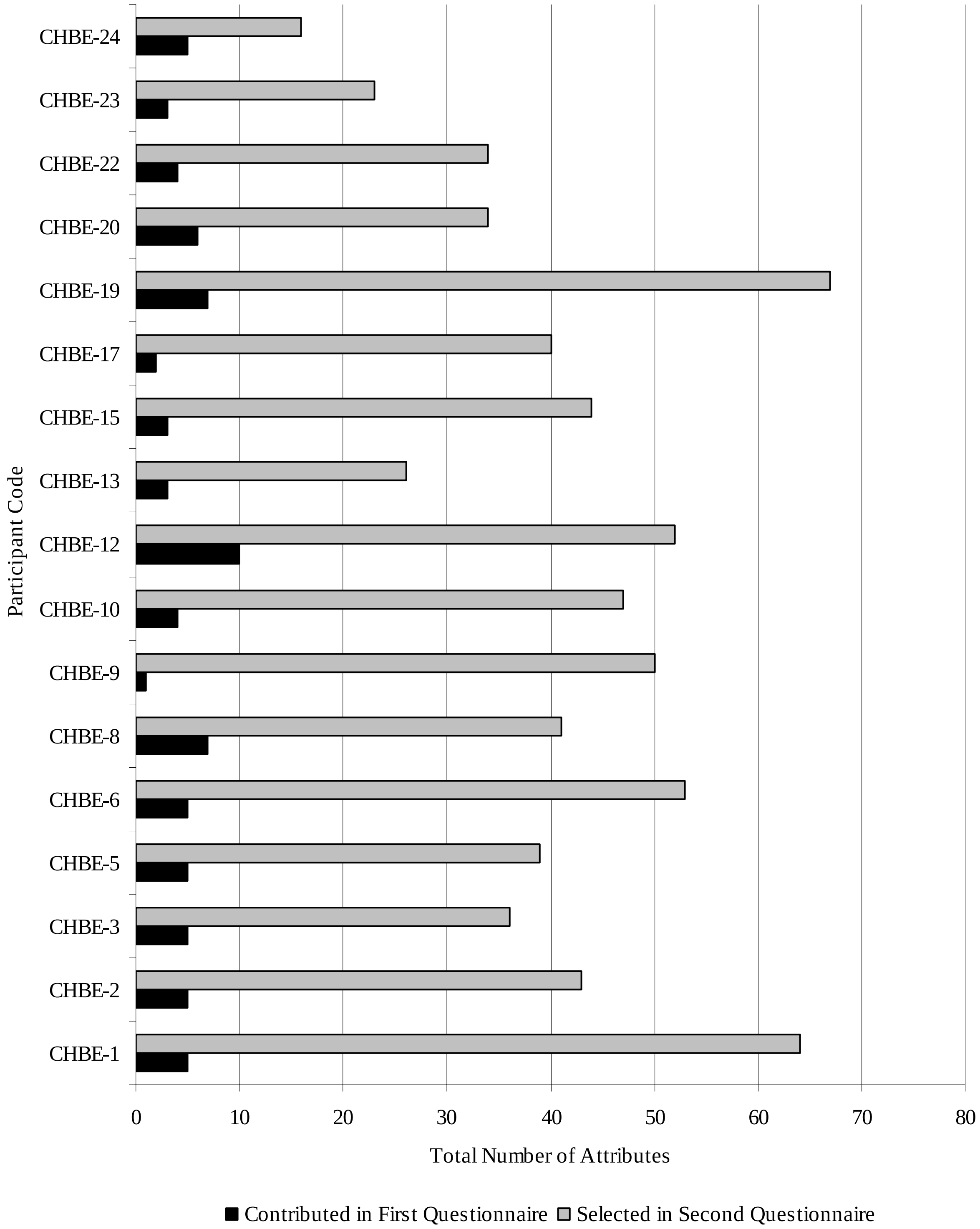

Figure 2. Comparison of the Total Number of Outcome Attributes Identified and Selected in Questionnaires 1 and 2 by Each CHE Respondent

Table 36. Average Number of Outcome Attributes Identified for the Definition of Contextual Competence by Each CHE Respondent in Questionnaire 1 and Selected for the Definition of Contextual Competence in Questionnaire 2, Distributed by the Source Category

Source of Outcome Attributes from Questionnaire 1	Attributes Used by CHE Respondents to Define Contextual Competence: Questionnaire 1	Attributes Used by CHE Respondents to Define Contextual Competence: Questionnaire 2
Engineering Respondents Only (N=34)	4	24
HSS Respondents Only (N=26)	0	12
Both Engineering and HSS Respondents (N=10)	1	6
Total (N=70)	5	42

Table 37. Outcome Attributes Identified, Selected and Added by Each CHE Respondent, as a Percentage of All Attributes Available in Each Source Category

Source Category	Percentage of All Attributes in Each Source Category, %: Attributes Identified in Questionnaire 1, %	Percentage of All Attributes in Each Source Category, %: Attributes Selected in Questionnaire 2, %
Engineering Respondents Only (N=34)	12	69
HSS Respondents Only (N=26)	0	48
Both Engineering and HSS Respondents (N=10)	6	57
Total	7	60

Table 38. Outcome Attributes Identified, Selected and Added by the CHE Respondents, Distributed by Source Category

	Average Distribution of Attributes, %		
Source Category	Attributes Identified in Questionnaire 1, %	Attributes Selected in Questionnaire 2, %	Attributes Added in Questionnaire 2, %
Engineering Respondents Only (N=34)	84	57	53
HSS Respondents Only (N=26)	0	29	33
Both Engineering and HSS Respondents (N=10)	16	14	14
	100%	100%	100%

CHAPTER 5

CONCLUSIONS

The purpose of this study was to develop a protocol for exploring how faculty members in an academic program perceive a multidisciplinary outcome (its definition, its relationship to courses in the curriculum, and methods for assessing it), and to demonstrate the use of the protocol in a particular academic program in engineering. The case study provides a detailed description of how faculty members in chemical engineering and the humanities and social sciences at Georgia Tech perceive contextual competence, an educational objective that crosses disciplinary boundaries and lies in the common ground between general education and the major. What distinguishes this study from previous work is the holistic exploration of these issues within a specific academic program—the context in which such issues should be addressed—rather than the multi-institution contexts of previous studies. This level of analysis provides guidance to program administrators on how to approach the enduring challenge of integrating learning across the two stems of the engineering curriculum. It addresses the fundamental challenges to curriculum coherence: the development of shared goals and objectives among faculty members responsible for general education and the major, and the selection of relevant courses and evaluation methods to achieve these objectives.

Summary of the Findings

Research Question 1

> How do faculty members in engineering and in the humanities and social sciences define contextual competence?

The definition of contextual competence for respondents from both groups of faculty involves the following: engineering practice and decision making in context, an understanding of the relationship between technology and society, the ability to apply economic principles to business situations, and a commitment to ethical behavior as an individual and as a professional. The specific attributes of contextual competence are summarized in Table 20 of Chapter 4. Within this set of attributes, the chemical engineering respondents often place more emphasis on the application of knowledge and skills in the engineering profession. In addition to the competencies in the four areas shared in common by the respondents, the chemical engineering respondents include in their definition competencies related to product and process safety, while the humanities and social science respondents include competencies related to diverse cultures and values, and human behavior and technology. Finally, only the chemical engineering respondents specifically mention environmental protection and sustainability in their definition of contextual competence. After refinement in the second questionnaire, the definition of contextual competence for the chemical engineering respondents expanded to include a total of 44 outcome attributes, including one related to diverse cultures and values. The definition did not include competencies in human behavior and technology.

The chemical engineering respondents would evaluate half of the 44 outcome attributes they included in the definition of contextual competence as part of a self-study for ABET accreditation. These include many competencies assessed in existing chemical engineering courses, e.g., technical competencies associated with engineering practice in context and process safety. The competencies they selected for the definition of contextual competence, but not for evaluation, include most of competencies related to diverse cultures and values, economics, and ethics. In general, these competencies require students to understand, assess, evaluate and/or judge issues involving societal interests, needs, and impacts, or ethics and human values. For the most part, these competencies require qualitative evaluation methods. One exception is the competency on sustainability selected for evaluation by a majority of the chemical engineering respondents:

- Students should have the ability to understand issues of sustainability and the impact of professional engineering work on the production of global, societal well-being (in terms of economic, ethical and environmental quality) and quality of life (in terms of convenience, health, environment, safety, and the economy).

Research Question 2

> In which courses in the undergraduate curriculum do faculty members in engineering and in the humanities and social sciences believe contextual competence is best developed?

A large proportion of respondents in chemical engineering and the humanities and social sciences believe that contextual competence is developed best through coursework in both engineering and the humanities and social sciences. The respondents differ in opinion on the relative contribution of coursework in the major versus general education to the development of contextual competence. Chemical engineering respondents believe contextual competence is developed primarily through coursework in engineering, while respondents in the humanities and social sciences believe it is developed primarily through coursework in humanities and social sciences.

Contextual competence is a major or minor objective of several courses in the four-year chemical engineering curriculum. Over 90% of the chemical engineering respondents identified the one-credit course on Process Safety (CHBE 4515) and 65% the three-credit course on Process Design and Economics (CHBE 4505) as having contextual competence as a major objective. The respondents in the humanities and social sciences provided a list of two dozen courses in which contextual competence is a major objective. Seven of these courses were in subjects related to technology and society and four courses addressed ethics and human values. The HSS course list includes four of the courses taken most often by the chemical engineering students who graduated in May 2003: (1) economics and policy, (2) American government, (3) science, technology and human values, and (4) general psychology. While the HSS respondents did not specifically mention environmental protection or sustainability in their definition of contextual competence, they included four courses on those topics as having contextual competence as a major objective, and three courses in which it is a minor objective.

Research Question 3

> Do faculty in engineering and in the humanities and social sciences believe that adequate emphasis is placed on contextual competence in courses in engineering or in courses in the humanities and social sciences?

Chemical engineering respondents believe the level of emphasis on contextual competence in courses in engineering and in the humanities and social sciences is inadequate, and they would like to have more emphasis on contextual competence in these courses. The humanities and social science respondents are split in opinion on the level of emphasis on contextual competence in courses in either engineering or the humanities and social sciences. A number of HSS respondents believe the issue is not the level of emphasis on contextual competence in the courses, but the level of integration of content relevant to the outcome between courses in engineering and the humanities and social sciences.

Research Question 4

> How would faculty members in engineering and in the humanities and social sciences evaluate student achievement of contextual competence? When and where (e.g., in what courses) in the academic program would they evaluate student achievement?

A majority of respondents in both chemical engineering and humanities and social sciences would evaluate contextual competence using a technical problem or project. For the chemical engineering respondents, the problem would involve significant technical analyses that incorporate contextual factors. The humanities and social science respondents would focus on the ethical and social issues surrounding a technological problem. Students would demonstrate their competency through written and oral reports, and the evidence would be collected, as indicated by both groups of respondents, in capstone courses or other courses requiring open-ended projects. In addition to the capstone courses, respondents from both groups of faculty would collect evidence from many of their respective courses in the form of exam questions, projects, problems in homework assignments, and class discussions.

Research Question 5

> What effect does participation in the protocol have on how engineering faculty define contextual competence? Does the protocol provide useful information for faculty members interested in academic program improvement?

Participation in the two-questionnaire protocol significantly changed the definition of contextual competence for the chemical engineering faculty. On average they added 37 outcome attributes to their construct of contextual competence, increasing from an average of 5 to 42. Over one-fourth of the outcome attributes selected by the chemical engineering faculty were those contributed by their colleagues in the humanities and social sciences, a benefit of their indirect interaction. The influence of the protocol on the definition of contextual competence was acknowledged by 82% of the chemical engineering respondents, and 85% of the respondents indicated that they would use the results of the study in their undergraduate engineering program.

Social Connectedness of Faculty

Faculty discussions about contextual competence tend to occur among faculty members in the same discipline (e.g., in engineering or the humanities and social sciences). Contextual competence and the course-taking habits of engineering students in the humanities and social sciences had been discussed by many of the respondents in chemical engineering and the humanities and social sciences, but very few of the discussions involved faculty members from both engineering and the humanities and social sciences. In addition, the list of contacts provided by the respondents from both groups of faculty indicated they would more likely contact someone from their own disciplines for more information on contextual competence. While the lists of contacts are populated predominantly by individuals from the respondents' own disciplines, the majority of humanities and social science respondents included at least one engineering faculty member in their lists of contacts. Only a small proportion of the chemical engineering respondents included faculty members from the humanities and social sciences in their contact lists. The majority of the contacts identified by all of the respondents are faculty members at Georgia Tech. Nonetheless, nearly one-third of the chemical engineering respondents would only contact individuals from other institutions for more information on contextual competence.

Conclusions about the Use of the Protocol for Program Improvement

The protocol demonstrated in this study provides four types of information that can be used to implement a constructive dialogue on the socio-humanistic outcomes of the engineering curriculum among faculty in engineering and the humanities and social sciences. The conclusions from this study are organized by the four types of information.

1. Authenticity of the Protocol

The data on the authenticity of the protocol is essential for determining whether the results can be used as part of a dialogue process that will improve the effectiveness of the engineering program with respect to the multidisciplinary outcome of interest.

The chemical engineering respondents verified the authenticity of the protocol results for use in improving the effectiveness of their academic program with respect to the contextual competence outcome. The respondents indicated that participation in the two-questionnaire process changed their understanding of the concept of contextual competence. Their perception of this change was supported by the finding that the definition expanded significantly from an average of 5 outcome attributes to 42 for the chemical engineering respondents. In addition, the respondents indicated that they would use the results of the protocol in their academic program. The protocol results also demonstrate the value of indirect interaction between the faculty in chemical engineering and the humanities and social sciences. The definition of contextual competence selected by the chemical engineering respondents in the second questionnaire was enriched with outcome attributes contributed by their colleagues in the humanities and social sciences, attributes that had not been identified by any of the respondents in chemical engineering.

2. Construct Specificity

The definitions of contextual competence can be used to focus the dialogue process by increasing the construct specificity of the outcome for the particular academic context (e.g., the institutional mission, the objectives for general education and the major, and the nature of the faculty).

The definition of contextual competence was specified by the respondents in this study using 70 distinct outcome attributes in seven thematic areas. In the first questionnaire, the average respondent identified only three to five of the 70 outcome attributes. The results confirm the prediction of Besterfield-Sacre (2000) and her colleagues that contextual competence would have multiple definitions. When examined in aggregate, the definitions provided by the respondents address many of the same themes articulated in the national reports on the status of engineering education since the Mann Report in 1918. One example is the need for engineering students to understand the relationship between technology and society expressed by the authors of the Hammond Report (1940). The Hammond report stated that students should have "an understanding of the evolution of the social organization within which we live and of the influence of science and engineering on its development." The comparable outcome attribute selected by the chemical engineering respondents in this study indicates that students should be able to

> know, identify, describe and analyze the major domestic and foreign historical, political, cultural, economic and social forces that confront and define the United States and other countries of the world, and understand the role such forces play in technology development and the engineering profession.

3. Consensus of the Faculty

The data on outcome definitions, courses and evaluation methods can be used to determine the potential for using the common ground between general education and the engineering major as a foundation for a dialogue process on educational objectives between faculty in engineering and the humanities and social sciences.

Consensus on definitions. Many of the outcome attributes for contextual competence selected by the chemical engineering respondents correspond directly to the objectives of general education at Georgia Tech. This finding concurs with the findings of Stark and others on the common objectives of general and professional education (Gross, 1988; Opper, 1992; Stark, 1987; Stark & Lowther, 1989). In some cases, the outcome attributes correspond directly to the outcomes of the general education program. One example is the outcome on technology and society described in the previous section. This outcome corresponds to the scientific culture and values objective of the general education program (Georgia Institute of Technology, 2002a):

> Georgia Tech students will demonstrate knowledge of the dynamic relationships among science, technology, cultural values, and creative expression and how these relationships must be framed by ethical principles. [In particular] students will be able to:
>
> - identify the interaction between science and technology and social, historical, political, and economic values.
> - identify ethical issues relating to the application of science and technology.

In other cases, the outcome attributes extend the learning in general education through application to engineering practice. For example, the chemical engineering respondents selected the following outcome attribute related to diverse cultures and values:

> Students should be able to understand the social and cultural values that are *embodied in* engineering design and practices, including how engineering practices depend on assumptions about the characteristics of users (e.g., their education, attitudes, wealth, goals) and their societies (e.g., how economic or political processes will put a technology into practice).

In the general education program, the corresponding outcome is found under the objective for student learning in global awareness, human values and culture. It states that students should be able to “demonstrate knowledge of the diversity of values and traditions, including the contributions of diverse groups, which shape society and institutions” (Georgia Institute of Technology, 2002a).

<u>Consensus on courses.</u> The respondents agree that coursework in both general education and the major contributes to the development of contextual competence in students, but they do not agree on whether the development occurs primarily in coursework in engineering or in the

humanities and social sciences. The chemical engineering respondents believe that contextual competence is developed primarily through coursework in engineering. This finding has precedents in the literature. Two previous studies of engineering faculty found that they did not believe coursework in the humanities and social sciences contributed significantly to the development of contextual competence in engineering students (Stark, Lowther, & Hagerty, 1986; Vandermeer & Lyons, 1979). Conversely, the respondents in the humanities and social sciences believe that contextual competence is developed primarily through coursework in the humanities and social sciences.

The chemical engineering respondents believe that more emphasis should be placed on contextual competence in courses in engineering and the humanities and social sciences. The respondents in the humanities and social sciences, however, do not share a common belief about the emphasis on contextual competence in courses. Several HSS respondents suggested that the issue is integration of objectives and content across the courses and not the level of emphasis on contextual competence in courses in either component of the curriculum. This sentiment is shared by the authors of the national reports on engineering education since Wickenden called for a unified curriculum in 1930 (Wickenden, 1930) and by Stark and her colleagues in their studies of the common ground between general and professional education (Stark, 1986, 1987, 1989; Stark & Lowther, 1989)

<u>Consensus on evaluation methods.</u> The respondents would use similar methods for evaluating contextual competence, but their methods present complementary perspectives on problems involving the relationship between engineering and the broader societal context. The chemical engineering respondents would focus on technical problem-solving that incorporates contextual considerations, while the respondents in the humanities and social sciences would

focus on the evaluation of contextual issues (e.g., social and ethical issues) associated with a technological problem. Both groups of respondents would evaluate contextual competence using written and oral reports from capstone or other courses that focus on open-ended projects or evidence routinely collected in courses throughout the curriculum.

4. Social Connectedness

The data on the social connectedness among faculty members can be used to assess the potential for implementing a constructive dialogue process. The potential is determined by the amount of interaction that exists among the faculty in engineering and the humanities and social sciences.

The current level of interaction between respondents in chemical engineering and the humanities and social sciences provides limited opportunities for implementing a dialogue process on shared educational objectives. The patterns of social connectedness reported by the respondents in this study support Stark's findings on the relatively low level of interaction between faculty in engineering and the humanities and social sciences (Stark & Lowther, 1986, 1989; Stark, Lowther, & Hagerty, 1986). The humanities and social science respondents in this study reported a significant level of involvement in discussions about contextual competence and the course-taking patterns of engineering students. They also included engineering faculty in their lists of contacts. This can be attributed in part to the influence of the questionnaire topic (contextual competence in the engineering curriculum) and to the centrality of engineering to the mission of Georgia Tech. While most of the respondents from chemical engineering and the humanities and social sciences reported participating in discussions with their colleagues about contextual competence and how engineering students would develop it, very few reported participating in specific teaching, research, or committee service activities involving faculty from both engineering and the humanities and social sciences.

Implications of the Protocol Results for the Case Study

The study results can be used by the administrators of the chemical engineering and general education programs at Georgia Tech for improvement of these programs with respect to the contextual competence objective of engineering education and related objectives in the general education program. A dialogue process on shared educational objectives could focus on those outcome attributes, selected by the chemical engineering faculty for inclusion in the definition of contextual competence, that are related directly to the objectives of general education. The dialogue process could be implemented under the auspices of the faculty curriculum committee at the university level, or within the self-study process for the chemical engineering program for accreditation by ABET. More discussion among the faculty is needed to determine whether relevant content for these shared outcomes should be integrated into courses in engineering or the humanities and social sciences, or whether the curriculum effort should involve integration of content across existing courses in engineering and the humanities and social sciences. In either case, the faculty can begin the discussion on courses and content by examining the relatively short list of courses in which contextual competence is a major objective that they identified in the first questionnaire of the protocol.

Recommendations for Further Study

The use of the protocol results for academic program improvement, described in the previous section, could provide opportunities for research on the influence of multidisciplinary discussions on engineering faculty constructs for the concept of contextual competence and attitudes toward coursework in the humanities and social sciences. The recommendations for further study described in this section, however, focus on three studies to explore the utility of the protocol for (1) inter-institutional research on the influence of institutional factors on faculty objectives, (2) intra-institutional research on the relationship between faculty objectives and student outcomes, and (3) intra-institutional research on the influence of the engineering disciplines on faculty objectives.

Research on Institutional Factors

The two questionnaires in the protocol can be adapted to examine the effect of institutional mission, general education policy, and the discipline on the definition of contextual competence by chemical engineering faculty and their attitudes toward coursework in the humanities and social sciences. One motivation for selecting the particular study site was its potential interest to faculty and administrators of chemical engineering programs at similar institutions. The relevance of this study to other chemical engineering programs was based on the assumption that the chemical engineering discipline would have a strong socialization effect on faculty, resulting in similar definitions for the outcome and attitudes toward the humanities and social sciences among chemical engineering faculty in different doctoral-level institutions. Furthermore, it was assumed that the general education policy of the institution would influence the way chemical engineering faculty defined the outcome and viewed the contribution of coursework in the humanities and social sciences to the development of the competency in engineering students.

The study to examine the influence of institutional mission, general education policy, and discipline on the contextual competence outcome would involve chemical engineering faculty in different institutional contexts where one might find a higher level of shared objectives and curricular content between general education and the major or a higher level of interaction between faculty in engineering and the humanities and social sciences. The study would use Questionnaire 2 as implemented in this study to characterize the definition of contextual competence. It would also use a shortened version of Questionnaire 1 to solicit information on faculty attitudes toward coursework in the curriculum and the social connectedness between faculty in engineering and the humanities and social sciences. Questionnaire 1 would be modified to eliminate the open-ended question on the definition of contextual competence (item 1) and to reflect the specific chemical engineering courses in the curriculum of the institution (item 7). The rationale for eliminating the open-ended question on the definition of contextual competence is that the list of 70 outcome attributes identified by the faculty in this study is sufficiently comprehensive. The completeness of the outcome attribute set can be tested by including a section in Questionnaire 2 for respondents to provide additional outcome attributes.

Research on Faculty Objectives and Student Outcomes

Questionnaire 2 can be adapted for use in a study of the contextual competency of chemical engineering students. Using the same case study site and academic program, the objective would be to examine the relationship between student self-assessments of contextual competence and the operational definition of the outcome shared by the faculty. The student outcome data can be obtained from student self-assessments using a questionnaire adapted from the 70 outcome attribute statements on Questionnaire 2. Prior to graduation, students in the program would be asked to rate their ability on each of the outcome attributes using a Likert-type scale. The students' self-assessment data on the 70 outcome attributes would be compared to the subset of 44 outcome attributes selected by the faculty for inclusion in the definition of contextual competence. A group of students would then be selected for exit interviews to explore any connections they draw between their self-assessed competencies and learning in courses they took in the curriculum. The same study of student outcomes could be conducted in chemical engineering programs at other institutions for which baseline data on the faculty definition of contextual competence has been developed (as described in the preceding inter-institutional study).

Research on Engineering Disciplines

Finally, the two-questionnaire protocol could be adapted and used to explore whether the particular engineering discipline influences the way engineering faculty define contextual competence and perceive the importance of coursework in the humanities and social sciences to the development of it. The nature of the context differs for engineers practicing and teaching in the different engineering disciplines, e.g., the contextual issues considered by a civil engineer designing a bridge are different from those considered by an electrical engineer designing a microprocessor. The study would be based on a multiple case study design with two or more engineering programs in the same institution with the same general education policy. Such a study could involve the implementation of two-questionnaire protocol with faculty in selected engineering disciplines at Georgia Tech. Questionnaire 1 would include the open-ended question on definition of contextual competence (item 1) and be modified to reflect the particular core engineering courses of the academic programs (item 7). A transcript analysis of a graduating cohort in the selected engineering disciplines would be conducted to determine whether the responses from the humanities and social sciences faculty in the chemical engineering study would be appropriate for use in the comparative study.

Concluding Remarks

In summary, this study addresses the need for contextually relevant data for improving academic programs with respect to multidisciplinary outcomes that encompass learning in engineering and the humanities and social sciences. The holistic exploration of a multidisciplinary outcome within a specific academic program, rather than the multi-institution contexts of previous studies, provides authentic information for faculty and administrators to use to improve the effectiveness of their academic program. While the protocol developed for this study serves the specific needs of faculty in an academic program, it also provides a method for exploring the role of disciplinary and institutional culture on faculty perceptions of such multidisciplinary outcomes. Such research is needed to bridge the gap between the abstract knowledge gained from prior research and the concrete knowledge about engineering faculty in a specific academic program. Such research is needed to increase the utility of curricular research for increasing coherence in the undergraduate engineering curriculum.

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APPENDICES

Appendix A. Criteria for Accrediting Engineering Programs

(ABET Engineering Accreditation Commission, 2003)

I. GENERAL CRITERIA FOR BASIC LEVEL PROGRAMS

It is the responsibility of the institution seeking accreditation of an engineering program to demonstrate clearly that the program meets the following criteria.

Criterion 1. Students

The quality and performance of the students and graduates are important considerations in the evaluation of an engineering program. The institution must evaluate, advise, and monitor students to determine its success in meeting program objectives.

The institution must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere. The institution must also have and enforce procedures to assure that all students meet all program requirements.

Criterion 2. Program Educational Objectives

Each engineering program for which an institution seeks accreditation or reaccreditation must have in place:

(a) detailed published educational objectives that are consistent with the mission of the institution and these criteria
(b) a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated
(c) a curriculum and processes that ensure the achievement of these objectives
(d) a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program.

Criterion 3. Program Outcomes and Assessment

Engineering programs must demonstrate that their graduates have:

(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.

Each program must have an assessment process with documented results. Evidence must be given that the results are applied to the further development and improvement of the program. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program, including those listed above, are being measured. Evidence that may be used includes, but is not limited to the following: student portfolios, including design projects; nationally-normed subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates.

Criterion 4. Professional Component

The professional component requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The engineering faculty must assure that the program curriculum devotes adequate attention and time to each component, consistent with the objectives of the program and institution. Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political. The professional component must include:

(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline
(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study
(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

Criterion 5. Faculty

The faculty is the heart of any educational program. The faculty must be of sufficient number; and must have the competencies to cover all of the curricular areas of the program. There must be sufficient faculty to accommodate adequate levels of student-faculty interaction, student advising and counseling, university service activities, professional development, and interactions with industrial and professional practitioners, as well as employers of students. The program faculty must have appropriate qualifications and must have and demonstrate sufficient authority to ensure the proper guidance of the program and to develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and registration as Professional Engineers.

Criterion 6. Facilities

Classrooms, laboratories, and associated equipment must be adequate to accomplish the program objectives and provide an atmosphere conducive to learning. Appropriate facilities must be available to foster faculty-student interaction and to create a climate that encourages professional development and professional activities. Programs must provide opportunities for students to learn the use of modern engineering tools. Computing and information infrastructures must be in place to support the scholarly activities of the students and faculty and the educational objectives of the institution.

Criterion 7. Institutional Support and Financial Resources

Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the engineering program. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the engineering program. In addition, support personnel and institutional services must be adequate to meet program needs.

Criterion 8. Program Criteria

Each program must satisfy applicable Program Criteria (if any). Program Criteria provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline. Requirements stipulated in the Program Criteria are limited to the areas of curricular topics and faculty qualifications. If a program, by virtue of its title, becomes subject to two or more sets of Program Criteria, then that program must satisfy each set of Program Criteria; however, overlapping requirements need to be satisfied only once.

II. GENERAL CRITERIA FOR ADVANCED LEVEL PROGRAMS

Criteria for advanced level programs are the same as for basic level programs with the following additions: one year of study beyond the basic level and an engineering project or research activity resulting in a report that demonstrates both mastery of the subject matter and a high level of communication skills.

Appendix B. Core Curriculum Requirements

University System of Georgia Core Curriculum Principles and Framework

The principles and curricular framework were developed by the Administrative Committee on Undergraduate Education (Undergraduate Council), the Executive Committee of the Administrative Committee on Academic Affairs, and Academic Affairs staff and revised based upon suggestions from the institutions. The principles and framework were developed with the goal of allowing institutions some flexibility in defining learning outcomes while ensuring that the core curriculum completed at one System institution is fully transferable to another System institution.

POLICY

303.01 CORE CURRICULUM

Each institution's core curriculum shall follow a common set of principles and framework. The System principles and framework were developed with the goal of allowing institutions some flexibility in defining learning outcomes while ensuring that the core curriculum completed at one System institution is fully transferable to another System institution.

Each institution's core curriculum shall consist of 60 semester hours as follows:

Area A	Essential Skills Specific courses in English composition and mathematics	9 semester hours
Area B	Institutional Options Courses that address institution-wide general education outcomes of the institution's choosing	4-5 semester hours
Area C	Humanities/Fine Arts Courses that address humanities/fine arts learning outcomes	6 semester hours
Area D	Science, Mathematics, and Technology Courses that address learning outcomes in the sciences, mathematics, and technology	10-11 semester hours
Area E	Social Sciences Courses that address learning outcomes in the social sciences	12 semester hours
Area F	Courses Related to the Program of Study Lower division courses related to the discipline(s) of the program of study and courses that are prerequisite to major courses at higher levels.	18 semester hours

The specific courses contained in areas A through E of an institution's core curriculum are approved by the Council on General Education.

Students completing an area of the core curriculum will receive full credit for that area upon transfer to another System institution within the same major. In area A, students will receive credit for courses taken regardless of whether the area is completed. For students completing the core curriculum, the total number of hours required of transfer students for the baccalaureate degree shall not exceed the number of hours required of native students for the same major field.

PROCEDURES

Institutions in the University System shall offer a Core Curriculum as follows:

<u>Principles Across the Core That Are Common to All Institutions</u>

Each institution's core curriculum shall:

1. Encourage the development of written and oral communication skills and critical thinking within the broader academic context;
2. Permit opportunities for interdisciplinary learning;
3. Include offerings that reflect the special characteristics of the institution;
4. Feature international components that increase global awareness and introduce the student to different cultural perspectives;
5. Include an informed use of information technology;
6. Employ pedagogy designed to increase intellectual curiosity and to initiate a continuing interest in the subject matter;
7. Feature courses that are challenging and rigorous and provide learning experiences that distinguish a field;
8. Introduce the methods used by technical and scientific professionals such as the evaluation of empirical data, problem recognition, problem definition, the application of scientific principles, and logical problem solving;
9. Be cohesive and provide entry to both specialized studies in the student's chosen field and remaining courses (whether upper or lower division) in the institution's general education curriculum; and
10. Be designed with the assumption that students have met all admissions standards to the institution (with appropriate academic support provided for those who have not).

<u>Curricular Framework for the Common Core 60 Semester Hours</u>

A. Essential Skills 9 semester hours

   The following courses shall have common course numbers throughout the University System. Each course in this section (A) shall be three semester hours:

   a. English Composition I
   b. English Composition II
   c. College Algebra (or) Mathematical Modeling (or other courses approved by the Council on General Education)

   More advanced mathematical courses may be required for certain majors and/or institutions with the approval of the Council on General Education.

   Transfer: Course-by-course. Any higher level course or more advanced requirements must apply equally to native and transfer students.

B. Institutional Options 4 - 5 semester hours

Courses approved by the Council on General Education which address institution-wide general education outcomes of the institution's choosing. Examples include, but are not limited to, global issues, oral communication, information technology, critical thinking, wellness, geography, and foreign languages.

Transfer: If B is completed, the receiving institution must accept this area in its entirety.

C. Humanities/Fine Arts 6 semester hours

Courses which address humanities/fine arts learning outcomes and which have been approved by the Council on General Education. Interdisciplinary courses are acceptable.

Transfer: If C is complete, the receiving institution must accept this area in its entirety.

D. Science, Mathematics, and Technology 10 - 11 semester hours

Courses approved by the Council on General Education which address learning outcomes in the sciences, mathematics, and technology. These need not be sequential courses. Interdisciplinary courses are acceptable.

Students complete one of two options:

Option I - Non-Science Majors

d. A four-hour laboratory or a three or four-hour non-laboratory course, and
e. A four-hour laboratory course.
f. Three additional credit hours in mathematics, science, or technology.

Option II - Science Majors

g. Two four-hour laboratory courses.
h. Same as number 3 in Option I above.

Transfer: If D is complete, the receiving institution must accept this area in its entirety.

E. Social Sciences 12 semester hours

Courses approved by the Council on General Education which address learning outcomes in the social sciences including, but not limited to, history and American government. Interdisciplinary courses are acceptable. If credit work is used to satisfy the U.S./Georgia history and constitutions requirement, course(s) shall be part of this area.

Transfer: If E is complete, the receiving institution must accept this area in its entirety.

F. Courses Related to the Program of Study 18 semester hours

Lower-division courses related to the discipline(s) of the program of study and courses which are prerequisite to major courses at higher levels. Guidelines for acceptable courses in this area will be based on appropriate consultation with faculty in the relevant disciplines.

Transfer: If F is complete, the receiving institution must accept this area in its entirety.

Additional Transfer Guidelines

Provided that native and transfer students are treated equally, institutions may impose additional reasonable requirements such as a grade of "C" in English Composition.

For students who transfer after completing the core curriculum at a System institution, receiving institutions may require that these students complete the requirements as specified for native students; however, the total number of hours required of the transfer student for the baccalaureate degree shall not exceed the number of hours required of native students for the same major field.

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URL: http://www.usg.edu/admin/acadaff/handbook/section2/2.04/2.04.phtml

Georgia Institute of Technology Core Curriculum Requirements

CORE AREA A – Essential Skills (9 semester hours)

Area A is satisfied by completion of 10 semester hours as follows.
Required for all Majors:

Course	Class Title	Credit Hours
ENGL 1101	English Composition I	3 semester hours
ENGL 1102	English Composition II	3 semester hours

Required of all students majoring in the College of Architecture, Computing, Engineering and Sciences

Course	Class Title	Credit Hours
MATH 1501	Calculus I	4 semester hours

Required of all other Majors

Course	Class Title	Credit Hours
MATH 1712	Survey of Calculus	4 semester hours
MATH 1501	Calculus I	4 semester hours

CORE AREA B - Institutional Options (4 semester hours)

Area B is satisfied by students completing the following:
Electives approved by the program plus 1 hour from Area A

CORE AREA C - Humanities (6 semester hours)

The humanities requirement (Core Area C) is satisfied by completion of 6 semester hours from the following:

Architecture				
ARCH 2111	ARCH 4119	CP 4040	MUSI 4450	
ARCH 2112	ARCH 4120	CS 4752	MUSI 4801	
ARCH 2115	ARCH 4124	ID 2202	MUSI 4802	
ARCH 4109	ARCH 4128	MUSI 2600	MUSI 4803	
ARCH 4110	ARCH 4305	MUSI 3450	MUSI 4813	
ARCH 4113	COA 2241	MUSI 3500	MUSI 4823	
ARCH 4114	COA 2242	MUSI 3600	MUSI 4833	
ARCH 4117	COA 3115	MUSI 3610		
ARCH 4118	COA 3116	MUSI 3620		
Modern Languages				
CHIN 1002	FREN 1002	GRMN 1002	RUSS 1002	SPAN 3242
CHIN 2001	FREN 2001	GRMN 2001	RUSS 2001	SPAN 3691
CHIN 2002	FREN 2002	GRMN 2002	RUSS 2002	SPAN 3692
CHIN 2XXX	FREN 2021	GRMN 2XXX	RUSS 2XXX	SPAN 3693
CHIN 3003	FREN 2022	GRMN 3010	RUSS 3803	SPAN 3694
CHIN 3004	FREN 2XXX	GRMN 3011	RUSS 3813	SPAN 3811
CHIN 3021	FREN 3001	GRMN 3024	RUSS 3XXX	SPAN 3812
CHIN 3022	FREN 3002	GRMN 3025	RUSS 4811	SPAN 3813
CHIN 3811	FREN 3004	GRMN 3034	RUSS 4812	SPAN 3814
CHIN 3812	FREN 3007	GRMN 3035	RUSS 4813	SPAN 3815
CHIN 3813	FREN 3008	GRMN 3036	RUSS 4814	SPAN 3XXX
CHIN 3814	FREN 3011	GRMN 3071	RUSS 4815	SPAN 4061
CHIN 3815	FREN 3012	GRMN 3072	RUSS 4XXX	SPAN 4062
CHIN 3XXX	FREN 3030	GRMN 3695	SPAN 1002	SPAN 4141

CHIN 4811 CHIN 4812 CHIN 4813 CHIN 4814 CHIN 4815 CHIN 4XXX JAPN 1002 JAPN 1803 JAPN 1813 JAPN 3061 JAPN 3062 JAPN 3691 JAPN 2001 JAPN 2002 JAPN 2XXX JAPN 3001 JAPN 3002 JAPN 3692 JAPN 3693 JAPN 3XXX JAPN 4811 JAPN 4812 JAPN 4813 JAPN 4814 JAPN 4815 JAPN 4XXX	FREN 3061 FREN 3062 FREN 3121 FREN 3691 FREN 3692 FREN 3693 FREN 3694 FREN 3811 FREN 3812 FREN 3813 FREN 3814 FREN 3815 FREN 3XXX FREN 4001 FREN 4061 FREN 4062 FREN 4101 FREN 4102 FREN 4811 FREN 4812 FREN 4813 FREN 4814 FREN 4815 FREN 4XXX	GRMN 3696 GRMN 3697 GRMN 3811 GRMN 3812 GRMN 3813 GRMN 3814 GRMN 3815 GRMN 3XXX GRMN 4023 GRMN 4024 GRMN 4061 GRMN 4062 GRMN 4811 GRMN 4812 GRMN 4813 GRMN 4814 GRMN 4815 GRMN 4XXX	SPAN 1102 SPAN 1811 SPAN 1812 SPAN 1813 SPAN 1814 SPAN 1815 SPAN 2001 SPAN 2002 SPAN 2811 SPAN 2812 SPAN 2813 SPAN 2814 SPAN 2815 SPAN 2XXX SPAN 3061 SPAN 3062 SPAN 3101 SPAN 3102 SPAN 3111 SPAN 3112 SPAN 3121 SPAN 3122 SPAN 3170 SPAN 3235 SPAN 3236 SPAN 3241	SPAN 4142 SPAN 4151 SPAN 4152 SPAN 4154 SPAN 4170 SPAN 4255 SPAN 4811 SPAN 4812 SPAN 4813 SPAN 4814 SPAN 4815 SPAN 4XXX LING 2001 LING 2002 LING 3010 LING 3750 LING 3803 LING 3813 LING 4002 LING 4811 LING 4812 LING 4813 LING 4814 LING 4815
Literature, Communication, and Culture				
LCC 2100 LCC 2102 LCC 2104 LCC 2106 LCC 2108 LCC 2110 LCC 2112 LCC 2114 LCC 2116 LCC 2118 LCC 2202 LCC 2204 LCC 2206	LCC 2208 LCC 2210 LCC 2212 LCC 2214 LCC 2216 LCC 2218 LCC 2400 LCC 2500 LCC 2600 LCC 2813 LCC 2823 LCC 3202 LCC 3204	LCC 3206 LCC 3208 LCC 3210 LCC 3212 LCC 3214 LCC 3216 LCC 3218 LCC 3220 LCC 3222 LCC 3224 LCC 3226 LCC 3228 LCC 3234	LCC 3252 LCC 3254 LCC 3256 LCC 3262 LCC 3302 LCC 3304 LCC 3306 LCC 3308 LCC 3310 LCC 3314 LCC 3316 LCC 3318 LCC 3352	LCC 3362 LCC 3823 LCC 3833 LCC 3843 LCC 3853 LCC 3863 LCC 4204 LCC 4811 LCC 4812 LCC 4813 LCC 4814 LCC 4815
Philosophy of Science and Technology				
PST 1101 PST 2050 PST 2068 PST 3102 PST 3103 PST 3105	PST 3109 PST 3113 PST 3115 PST 3127 PST 4110 PST 4112	PST 4174 PST 4176 PST 4752 PST 4803 PST 4811 PST 4812	PST 4813 PST 4814 PST 4815	
Other				
ENGL 1101 ENGL 1102	HUM 1XXX HUM 21XX HUM 2XXX HUM 3XXX			

CORE AREA D - Science, Mathematics, & Technology (12 semester hours)

Area D is satisfied by students completing 8 semester hours from the science list, and 4 semester hours from the Mathematics list:

Course	Class Title	Credit Hours
CHEM 1310	General Chemistry	4 semester hours
CHEM 1311	Inorganic Chemistry I	3 semester hours
CHEM 1312	Inorganic Chem Lab	1 semester hours
BIOL 1510	Biological Principles	4 semester hours
BIOL 1511	Honors Biological Principals	4 semester hours
BIOL 1520	Intro to Organismal Biology	4 semester hours
BIOL 1521	Honors Intro to Organismal Biology	4 semester hours
EAS 1600	Intro to Environmental Field Science	4 semester hours
EAS 1601	Habitable Planet	4 semester hours
EAS 2600	Earth Processes	4 semester hours
PHYS 2211	Intro. Physics I	4 semester hours
PHYS 2212	Intro. Physics II	4 semester hours

Mathematics – All students with majors in the Colleges of Architecture, Computing, Engineering, and Science will complete:

Course	Class Title	Credit Hours
MATH 1502	Calculus II	4 semester hours

All other majors will complete:

Course	Class Title	Credit Hours
MATH 1711	Finite Mathematics	4 semester hours
MATH 1502	Calculus II	4 semester hours

CORE AREA E - Social Sciences (12 semester hours)

The social science requirement (Core Area E) is satisfied by completion of the U.S./Georgia history and constitution legislative requirement with three semester hours from: HIST 2111, 2112; POL 1101; INTA 1200; PUBP 3000; and nine semester hours from the following list.

Architecture, City and Regional Planning				
ARCH 4126	ARCH 4770	CP 4010		
ARCH 4335		CP 4020	CP 4030	
Economics				
ECON 2100	ECON 4340	ECON 4430	ECON 4510	ECON 4812
ECON 2105	ECON 4350	ECON 4440	ECON 4610	ECON 4813
ECON 2106	ECON 4411	ECON 4450	ECON 4620	ECON 4814
ECON 4160	ECON 4421	ECON 4460	ECON 4811	ECON 4815
ECON 4311				
History, History of Technology and Society				
HIST 2111	HTS 2803	HTS 3025	HTS 3085	HTS 4061
HIST 2112	HTS 2813	HTS 3026	HTS 3086	HTS 4062
HTS 1031	HTS 2823	HTS 3031	HTS 3101	HTS 4063
HTS 1081	HTS 2XXX	HTS 3032	HTS 3102	HTS 4064
HTS 2001	HTS 3001	HTS 3033	HTS 3803	HTS 4065
HTS 2002	HTS 3002	HTS 3035	HTS 3813	HTS 4081
HTS 2006	HTS 3003	HTS 3036	HTS 3823	HTS 4082
HTS 2007	HTS 3005	HTS 3038	HTS 4001	HTS 4083
HTS 2009	HTS 3006	HTS 3039	HTS 4002	HTS 4084
HTS 2011	HTS 3007	HTS 3041	HTS 4003	HTS 4085

HTS 2013 HTS 2016 HTS 2031 HTS 2032 HTS 2033 HTS 2036 HTS 2037 HTS 2061 HTS 2062 HTS 2081 HTS 2082 HTS 2084	HTS 3008 HTS 3011 HTS 3012 HTS 3015 HTS 3016 HTS 3017 HTS 3018 HTS 3019 HTS 3020 HTS 3021 HTS 3023 HTS 3024	HTS 3043 HTS 3045 HTS 3061 HTS 3062 HTS 3063 HTS 3064 HTS 3066 HTS 3067 HTS 3068 HTS 3082 HTS 3083 HTS 3084	HTS 4004 HTS 4005 HTS 4011 HTS 4012 HTS 4013 HTS 4014 HTS 4015 HTS 4031 HTS 4032 HTS 4033 HTS 4034 HTS 4035	HTS 4811 HTS 4812 HTS 4813 HTS 4814 HTS 4815 HTS 4823 HTS 4833 HTS 4843
International Affairs				
INTA 1110 INTA 1200 INTA 2030 INTA 2040 INTA 2100 INTA 2210 INTA 2220 INTA 2230 INTA 3010 INTA 3031 INTA 3101 INTA 3102 INTA 3103 INTA 3104 INTA 3110 INTA 3111 INTA 3120 INTA 3121 INTA 3130 INTA 3131 INTA 3201	INTA 3203 INTA 3220 INTA 3221 INTA 3230 INTA 3231 INTA 3240 INTA 3241 INTA 3301 INTA 3303 INTA 3304 INTA 3321 INTA 3330 INTA 3331 INTA 3750 INTA 3803 INTA 3813 INTA 4011 INTA 4040 INTA 4050 INTA 4101	INTA 4121 INTA 4230 INTA 4240 INTA 4241 INTA 4330 INTA 4331 INTA 4332 INTA 4340 INTA 4803 INTA 4811 INTA 4812 INTA 4813 INTA 4814 INTA 4815 INTA 4823 INTA 4833		
Political Science				
POL 1101	POL 2101			
Psychology				
PSYC 1101 PSYC 2010 PSYC 2020	PSYC 2103 PSYC 2210 PSYC 2220	PSYC 2230 PSYC 2240 PSYC 2270	PSYC 2300 PSYC 2400 PSYC 3060	PSYC 4770
Public Policy, Sociology, Social Science				
PUBP 2012 PUBP 2014 PUBP 3000 PUBP 3010 PUBP 3016 PUBP 3110 PUBP 3201 PUBP 3212	PUBP 3214 PUBP 3610 PUBP 4120 PUBP 4130 PUBP 4200 PUBP 4211 PUBP 4212 PUBP 4226	PUBP 4314 PUBP 4316 PUBP 4338 PUBP 4410 PUBP 4414 PUBP 4416 PUBP 4512 PUBP 4514	PUBP 4600 PUBP 4609 PUBP 4756 PUBP 4803 PUBP 4811 PUBP 4812 PUBP 4813 PUBP 4814	PUBP 4815 PUBP 4823 PUBP 4833 PUBP 4843 SOC 1101 SS 1XXX SS 2XXX

CORE AREA F - Courses Related to Degree & Major (18 semester hours)

Area F varies with degree and major

Appendix C. General Education Requirements for Georgia Tech Graduates

Final Report of the ad-hoc Subcommittee on General Education

January 2002

Revised August 2003

Bethany Bodo (Assistant Director, Office of Assessment), Carol Carmichael (Senior Research Scientist, Manufacturing Research Center), Fred Andrew (Professor, Mathematics), Bryan Church (Professor, Management), David Collard (Associate Professor, Chemistry), James Craig (Professor, Aerospace Engineering), Kurt Eiselt (Associate Dean, Computing), George Johnston (Associate Chair, Architecture), Gordon Kingsley (Associate Professor, Public Policy), Peter McGuire (Professor, Literature, Communication, and Culture), Scott Wills (Associate Professor, Electrical and Computer Engineering, Chair)

General Education Mission Statement

General Education at the Georgia Institute of Technology is essential to the development of our extraordinary students beyond the deeply rigorous technical and applied education they receive.

General Education at Georgia Tech is designed to produce student who are:
- Mathematically, scientifically, and technically competent;
- Competent in information research;
- Literate in reading, writing, and presenting; and
- Literate in the use of a computer.

Georgia Tech General Education is also designed to produce students who are able to:
- Think critically and
- Effectively collaborate with others.

Additionally, it strives to:
- Enhance students' awareness of scientific values and ethics;
- Enable them to articulate their personal and social values and how these values are shaped by the world around them;
- Encourage them to examine individual and social behaviors; and
- Develop their ability to effectively work in group settings.

General Education at Georgia Tech seeks to develop students who have an appreciation for technology, society, and their interaction and to produce students who will utilize these talents to substantially impact the future as leaders and lifelong learners.

Objectives and Outcomes

The committee identifies the following general education objectives for all students who earn a Georgia Tech baccalaureate degree. The objectives represent an effort to integrate the BOR general education requirements with the unique mission of Georgia Tech. Specifically, the objectives call for:

- Technical, mathematical, and scientific competence
- An ability to communicate to and productively interact with others
- An awareness of culture and values in a diverse world
- An understanding of ethical issues surrounding one's personal and professional activities

It is the opinion of the committee that a great strength of the Georgia Tech degree lays not only in the content but also in the exceptional quality of the programs and units that support these General Education requirements. The committee recommends these outstanding elements remain a part of all Georgia Tech degrees.

It is the recommendation of the committee that these objectives be implemented, whenever possible, in an integrated fashion through interdisciplinary courses, certificate programs, and minors.

Mathematics Objective: Georgia Tech students will be proficient in basic mathematical skills, able to formulate problems mathematically, able to use mathematical methods to solve original problems, and able to demonstrate an understanding of the nature of mathematical reasoning.

Outcomes

Students will be able to:

1. Apply basic elements of differential and integral calculus, and linear algebra to relevant problems.
2. Define fundamental mathematical concepts (such as induction, recursion, estimation, and approximation).
3. Given quantitative data, identify trends and other qualitative relationships.

Communication Objective: Georgia Tech students will be able to read a variety of documents critically, acquire and synthesize information, and shape a written or oral presentation that accommodates audience needs and shows a mastery of basic communications skills.

Outcomes

Students will be able to:

4. Locate the primary thesis in a written work and explain how it is supported by logical arguments.

5. Produce effective writing that supports a given thesis using clear prose, logical organization, and standard spelling, punctuation, and grammar.
6. Deliver a presentation that demonstrates effective core presentation skills, including focus, organization, and delivery.
7. Conduct an effective information search that includes a variety of reference sources (e.g., indexes and library catalogs, bibliographies, and Internet searches).

<u>Computer Literacy Objective</u>: Georgia Tech students will be able to use appropriate software applications effectively, demonstrate an understanding of the organization and operation of computer systems, and apply programming techniques to solve problems.

Outcomes

Students will be able to:

8. Describe the basic operation and organization of major computer hardware and software components, and the networking environments in which they operate.
9. Design, implement, and evaluate algorithms to solve a given problem within a programming environment.
10. Query a large database, combining quantitative results to support a thesis.

<u>Science Objective</u>: Georgia Tech students will demonstrate an understanding and application of scientific methodology, laboratory techniques, quantitative problem solving, modeling skills, and experimental design to formulate and evaluate hypotheses.

Outcomes

Students will be able to:

11. Describe how a hypothesis to explain natural phenomena is evaluated and refined through experimentation (e.g., the scientific method).
12. Demonstrate proper analysis of experimental data (e.g., error estimation, statistical analysis, noise rejection).
13. Apply knowledge of a scientific theory to practical problem solving.

<u>Scientific Culture and Values Objective</u>: Georgia Tech students will demonstrate knowledge of the dynamic relationships among science, technology, cultural values, and creative expression and how these relationships must be framed by ethical principles.

Outcomes

Students will be able to:

14. Identify the interaction between science and technology and social, historical, political, and economic values.
15. Identify ethical issues relating to the application of science and technology.

<u>Global Awareness, Human Values, and Culture Objective</u>: Georgia Tech students will be able to articulate their personal and social values, articulate how those values have been informed by

both humanistic and social perspectives, understand how these shape their view of the world, and compare these with other world values.

Outcomes

Students will be able to:

16. Demonstrate knowledge of the diversity of values and traditions, including the contributions of diverse groups, which shape society and institutions
17. Describe the organization and operation of a social or political system that governs society.
18. Relate significant historical events to their effects on contemporary society.

<u>Individual and Society Objective</u>: Georgia Tech students will be able to examine and conceptualize individual and social behaviors in disciplined and critical ways.

Outcomes

Students will be able to:

19. Identify and engage in distinctive modes of scientific and humanities-based inquiry appropriate to studying individual and social behavior.
20. Demonstrate dimensions of creativity, beyond analytic thought, including imagination, intuition, and metaphor.

<u>Group Involvement Objective</u>: Georgia Tech students will demonstrate their ability to work effectively in both face-to-face and electronic group contexts in order to achieve specified objectives.

Outcomes

Students will be able to:

21. Describe how complex problems can be solved in a multi-disciplinary group context.
22. Contribute effectively to the overall knowledge/ skills set of the group.
23. Participate in group interaction, including effective leadership, communication, integrating diverse approaches, and conflict resolution.

<u>Health and Wellness Objective</u>: Georgia Tech students will develop an understanding of the psychological and physiological bases of a healthy mental and physical lifestyle.

Outcomes

Students will be able to:

24. Explain the elements necessary to maintain a healthy lifestyle.
25. Describe of the impact of diet, activity, and genetics on health.

Source: (Georgia Institute of Technology, 2002a)

Appendix D. Data Collection Materials for Questionnaires 1 and 2

This appendix includes all of the materials used to test and implement the two questionnaires used in the protocol. Included are the following items:

- Questionnaire 1 Review Form. The Questionnaire 1 Review Form was used to pilot test the instrument. This form was distributed to ten individuals at Georgia Tech known by the researcher who had expertise in engineering education, ABET accreditation, general education, or research design.
- Letters from the School Chair and Dean. The respondents received the packages for Questionnaire 1 from the chair of the school or the dean of the college in March 2004.
- Consent Form. The consent form used in this study was approved by the Institutional Review Boards at the University of Georgia (Project Number H2004-10430-0) and the study site, the Georgia Institute of Technology (Protocol Number H04007).
- Email Reminder from the Researcher to the Faculty Members. The researcher followed up the initial distribution of the questionnaire packages using email messages addressed individually to the participants.
- Questionnaire 1 and Instructions. The questionnaire was printed on one sheet of 11” x 17” coverstock paper. The sample verb sheet was printed on a separate sheet of coverstock paper in yellow. Two versions of the questionnaire were created: the first for engineering faculty and the second for faculty in the humanities and social sciences. The questionnaire was distributed to the faculty in March 2004.
- Cover Letter/Instructions and Questionnaire 2. Questionnaire 2 was distributed to the engineering faculty, with a cover letter signed by the researcher, in August 2004. The questionnaire was printed on one sheet of 11” x 17” coverstock paper.

Questionnaire 1 Review Form

Carol Carmichael
404-894-5676

Thank you very much for agreeing to complete and review the attached questionnaire. The information you provide will be used only to improve the questionnaire instrument. I have attached a summary of the research project for which the questionnaire was developed and would be happy to discuss the overall research project with you at a future date.

As part of the review, I am asking you to do the following:

1. You will see that the questionnaire is intended for chemical engineering, but for the purposes of this review please complete questions #1-8 and 10 as if they were written for *your engineering discipline and academic department*.
2. Question #9 is specific to chemical engineering, so do not complete that question unless it is your department.
3. Please mark any comments directly on the questionnaire and/or on this review sheet.
4. Please complete the review questions on this sheet.
5. Please contact me by email and I will pick up the completed questionnaire and review form. Indicate in your message a date and time that would be convenient for me to do so.

Name of Reviewer: ____
Date Reviewed: ___________________

Is the language of each question clear, direct, and specific?

- Yes
- No

Please identify the numbers of any questions that are unclear and provide any additional comments you feel would be helpful in improving them.
____
____
____
____
____
(Use additional space on reverse side if needed.)

- Was the "Sample Verb List" useful in completing question #1?
  - Yes
  - No

- How long did it take you to complete the questionnaire? _______________ minutes.

Letter from School Chair to Engineering Faculty

From: School Chair

To: Faculty Member Name

Subject: Invitation to Participate in a Study

Study Name: Constructing the Concept of Contextual Competence in an Undergraduate Engineering Curriculum

I am encouraging you to participate in a research study titled “Constructing the Concept of Contextual Competence in an Undergraduate Engineering Curriculum” conducted by Carol Carmichael, a doctoral candidate at the Institute of Higher Education at the University of Georgia (404-894-5676), and a research scientist at Georgia Tech. You have been selected to participate based on your teaching experience in our undergraduate courses. Participation in the study is voluntary, and your contributions will not be attributed to you by name. Such details are described more fully on the consent form for participants included with this memorandum.

I believe this study will provide insight into how to address some of the non-technical outcomes in our engineering curriculum. Part of the study is a questionnaire designed to collect information on how we define the concept of contextual competence and how we believe students develop it in an undergraduate engineering curriculum. The questionnaire is included with this memorandum and should take about 30 minutes to complete. A smaller group of faculty will be invited to contribute materials from their courses and participate in meetings with the researcher to discuss further the concept and its representation in the curriculum. The total amount of time anticipated for participating in these activities is estimated to be between 30 and 90 minutes over a 3-month period.

Carol Carmichael will answer any further questions about the research. She can be reached by telephone at 404-894-5676, or by email at carol.carmichael@marc.gatech.edu.

Letter from Dean to Faculty in Humanities and Social Sciences

March 29, 2004

From: Dean of the Ivan Allen College

To: [Faculty Name]

Subject: Invitation to Participate in a Study

Study Name: Constructing the Concept of Contextual Competence in an Undergraduate Engineering Curriculum

I am encouraging you to participate in a research study titled “Constructing the Concept of Contextual Competence in an Undergraduate Engineering Curriculum” conducted by Carol Carmichael, a doctoral candidate at the Institute of Higher Education at the University of Georgia (404-894-5676), and a research scientist at Georgia Tech. You have been selected to participate based on your teaching experience in the undergraduate courses taken by chemical engineering students who graduated in May 2003. Participation in the study is voluntary, and your contributions will not be attributed to you by name. Such details are described more fully on the consent form for participants included with this memorandum.

This is a rare opportunity for the Ivan Allen College—represented by the professors responsible for courses in the humanities and social sciences taken by undergraduate engineering students—to help shape the definition of the more socio-humanistic outcomes of the engineering curriculum specified by ABET. As these outcomes share common ground with the general education outcomes of the Institute, the IAC will gain, in return, insight into how engineering faculty would define and assess such outcomes in their students. This will be especially useful to us as we continue to examine the IAC curriculum.

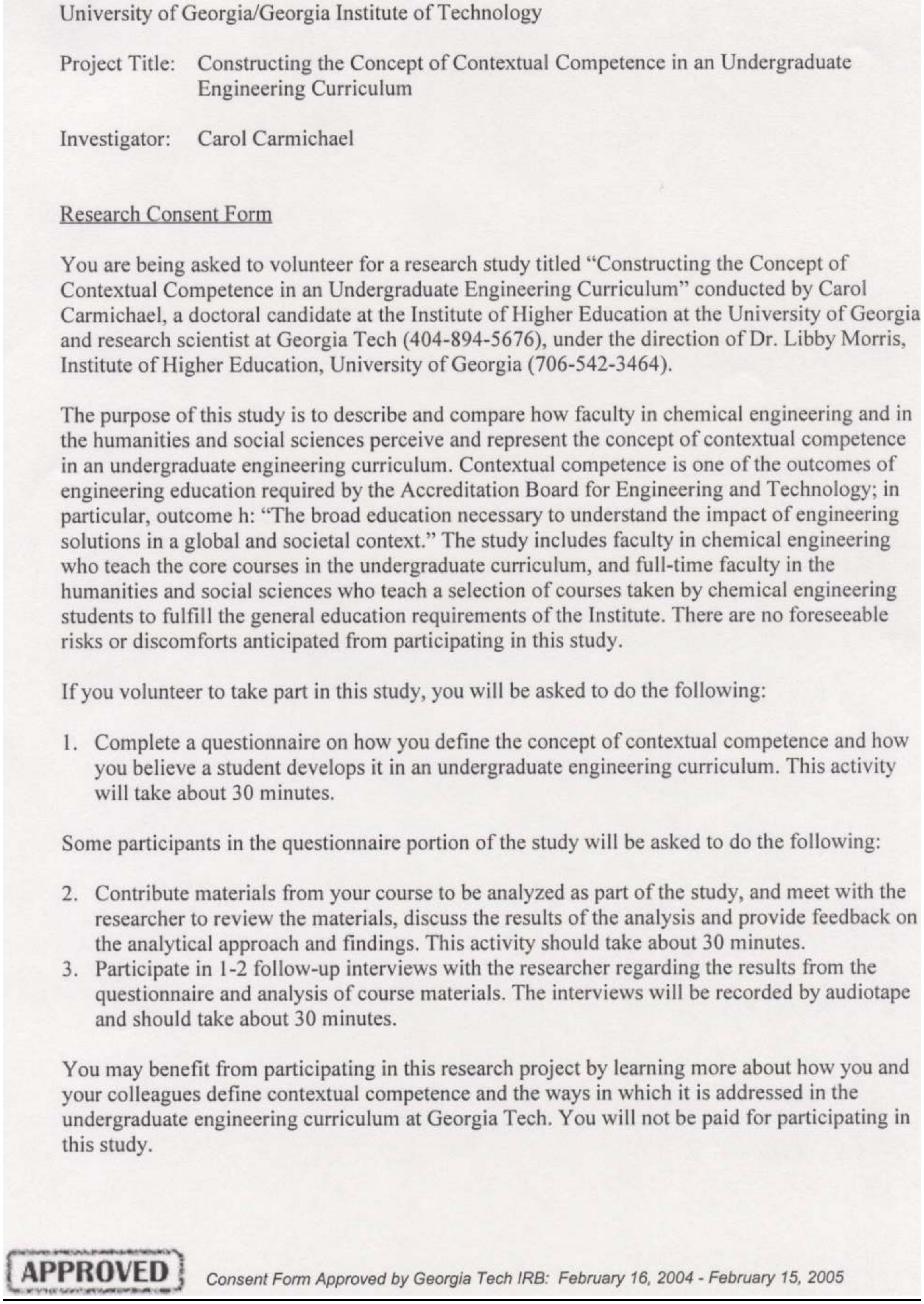
Part of the study is a questionnaire designed to collect information on how we define the concept of contextual competence and how we believe students develop it in an undergraduate engineering curriculum. The questionnaire is included with this memorandum and should take about 30 minutes to complete. Please complete the questionnaire by **April 15**, 2004.

A smaller group of faculty will be invited to contribute materials from their courses and participate in meetings with the researcher to discuss further the concept and its representation in the curriculum. The total amount of time anticipated for participating in these activities is estimated to be between 30 and 90 minutes over a 3-month period.

Carol Carmichael will answer any further questions about the research. She can be reached by telephone at 404-894-5676, or by email at carol.carmichael@marc.gatech.edu.

Thank you for participating.

Consent Form



University of Georgia/Georgia Institute of Technology

Project Title: Constructing the Concept of Contextual Competence in an Undergraduate Engineering Curriculum

Investigator: Carol Carmichael

Research Consent Form

You are being asked to volunteer for a research study titled "Constructing the Concept of Contextual Competence in an Undergraduate Engineering Curriculum" conducted by Carol Carmichael, a doctoral candidate at the Institute of Higher Education at the University of Georgia and research scientist at Georgia Tech (404-894-5676), under the direction of Dr. Libby Morris, Institute of Higher Education, University of Georgia (706-542-3464).

The purpose of this study is to describe and compare how faculty in chemical engineering and in the humanities and social sciences perceive and represent the concept of contextual competence in an undergraduate engineering curriculum. Contextual competence is one of the outcomes of engineering education required by the Accreditation Board for Engineering and Technology; in particular, outcome h: "The broad education necessary to understand the impact of engineering solutions in a global and societal context." The study includes faculty in chemical engineering who teach the core courses in the undergraduate curriculum, and full-time faculty in the humanities and social sciences who teach a selection of courses taken by chemical engineering students to fulfill the general education requirements of the Institute. There are no foreseeable risks or discomforts anticipated from participating in this study.

If you volunteer to take part in this study, you will be asked to do the following:

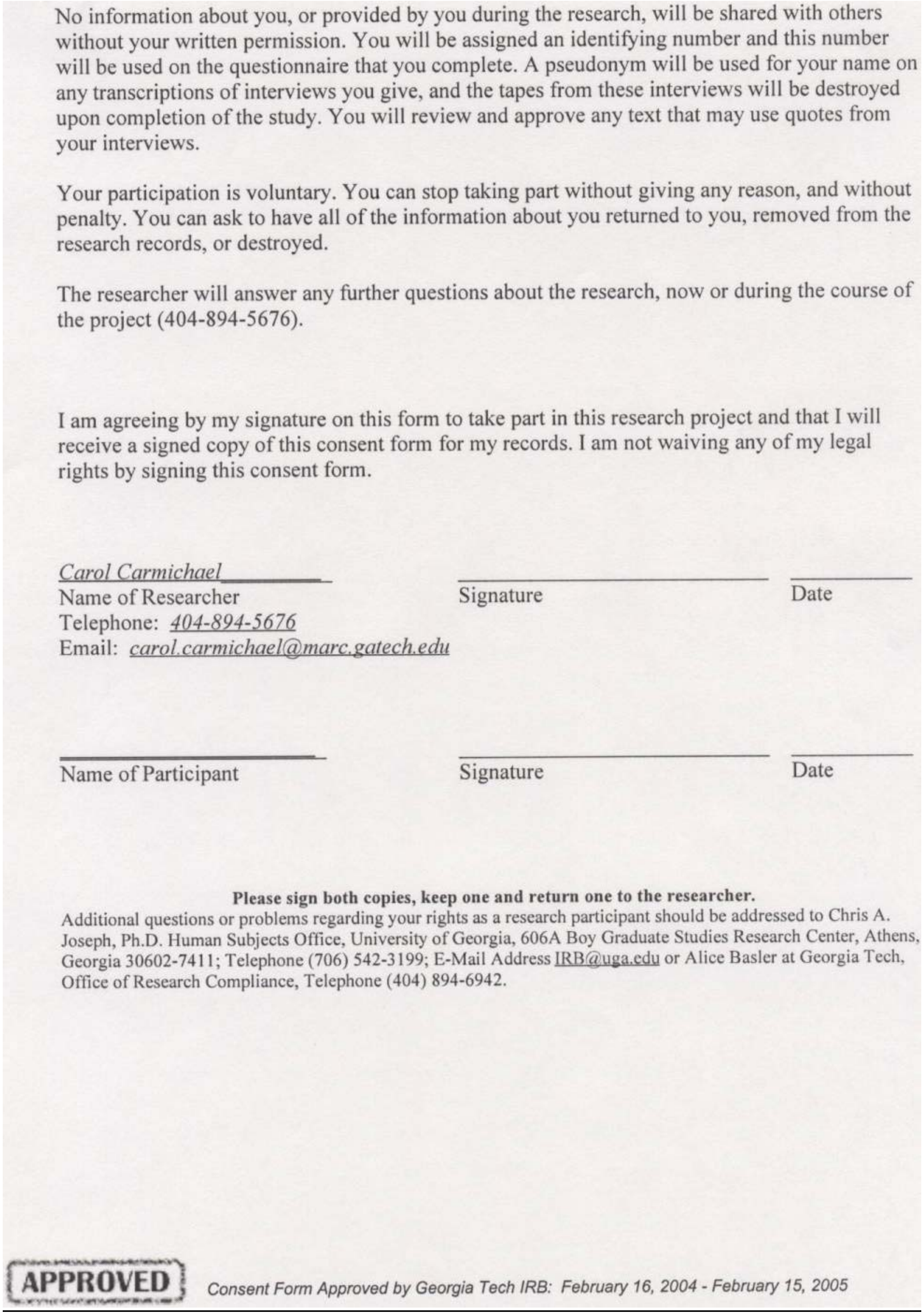
1. Complete a questionnaire on how you define the concept of contextual competence and how you believe a student develops it in an undergraduate engineering curriculum. This activity will take about 30 minutes.

Some participants in the questionnaire portion of the study will be asked to do the following:

2. Contribute materials from your course to be analyzed as part of the study, and meet with the researcher to review the materials, discuss the results of the analysis and provide feedback on the analytical approach and findings. This activity should take about 30 minutes.
3. Participate in 1-2 follow-up interviews with the researcher regarding the results from the questionnaire and analysis of course materials. The interviews will be recorded by audiotape and should take about 30 minutes.

You may benefit from participating in this research project by learning more about how you and your colleagues define contextual competence and the ways in which it is addressed in the undergraduate engineering curriculum at Georgia Tech. You will not be paid for participating in this study.

APPROVED *Consent Form Approved by Georgia Tech IRB: February 16, 2004 - February 15, 2005*



No information about you, or provided by you during the research, will be shared with others without your written permission. You will be assigned an identifying number and this number will be used on the questionnaire that you complete. A pseudonym will be used for your name on any transcriptions of interviews you give, and the tapes from these interviews will be destroyed upon completion of the study. You will review and approve any text that may use quotes from your interviews.

Your participation is voluntary. You can stop taking part without giving any reason, and without penalty. You can ask to have all of the information about you returned to you, removed from the research records, or destroyed.

The researcher will answer any further questions about the research, now or during the course of the project (404-894-5676).

I am agreeing by my signature on this form to take part in this research project and that I will receive a signed copy of this consent form for my records. I am not waiving any of my legal rights by signing this consent form.

*Carol Carmichael*______	______________________	__________
Name of Researcher	Signature	Date

Telephone: *404-894-5676*
Email: *carol.carmichael@marc.gatech.edu*

______________________	______________________	__________
Name of Participant	Signature	Date

Please sign both copies, keep one and return one to the researcher.

Additional questions or problems regarding your rights as a research participant should be addressed to Chris A. Joseph, Ph.D. Human Subjects Office, University of Georgia, 606A Boy Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu or Alice Basler at Georgia Tech, Office of Research Compliance, Telephone (404) 894-6942.

APPROVED *Consent Form Approved by Georgia Tech IRB: February 16, 2004 - February 15, 2005*

Email Reminder from the Researcher to Faculty Members

Dear Dr. [Faculty Name]

I want to thank you, in advance, for considering participation in my dissertation study entitled "Constructing the Concept of Contextual Competence in an Undergraduate Engineering Curriculum." I hope you have had time to review the materials distributed to you earlier this week. I will happy to answer any questions you may have about them.

I will be in your building on **Wednesday, March 31st**, to pick up completed questionnaires and consent forms for my study. I would like to know if there is a **convenient time that day** when I could **stop by your office to pick up your materials**. Please respond by email, if possible. Otherwise, you may reach me at 404-894-5676.

I appreciate your time and input in this study,

Sincerely,
Carol Carmichael

Instructions Provided to the Faculty for Questionnaire 1

CONTEXTUAL COMPETENCE IN THE UNDERGRADUATE ENGINEERING CURRICULUM

Please complete the questionnaire by [Date]

Thank you for agreeing to participate in this study. Please read the entire questionnaire before responding. Professors who have completed this questionnaire found that the first question takes the most time to complete, with the entire questionnaire taking about 30 minutes total to complete.

In this package you will find:

1. Two (2) copies of the participant consent form. Please sign both copies and keep one for your records. The second copy should be returned with the completed questionnaire.
2. One copy of the questionnaire and an attachment.
3. For questions #1, 2 and 3, you may type your responses on a separate sheet and attach the sheet to the questionnaire. Otherwise, you may write your responses by hand in the space provided on the questionnaire.

Carol Carmichael will contact you to arrange a convenient time to **pick up the questionnaire and consent form at your office.** If you wish, you may contact her at any time by telephone (404-894-5676) or by email (carol.carmichael@marc.gatech.edu).

CONTEXTUAL COMPETENCE IN THE UNDERGRADUATE ENGINEERING CURRICULUM
ENGINEERING FACULTY QUESTIONNAIRE

Please read the entire questionnaire before beginning to respond.

The objectives of an undergraduate engineering program include the development of competencies which are both technical and socio-humanistic in nature. This questionnaire is designed to capture faculty perspectives on criterion 3, outcome (h) of the ABET engineering criteria. In particular, this questionnaire focuses on outcome (h) as it pertains to the undergraduate chemical engineering curriculum.

Outcome (h): "The broad education necessary to understand the impact of engineering solutions in a global and societal context."

For the purposes of this questionnaire, this outcome will be referred to as **contextual competence**.

Definitions

One goal of this study is to identify the various ways in which faculty members in an academic program define and evaluate this outcome. Based upon your experience as a faculty member, please provide your perspective on the definition and evaluation of contextual competence *even if you do not directly address "contextual competence" in the courses that you teach.*

1) Please provide a more detailed definition for this outcome that you think is appropriate for graduates of the undergraduate chemical engineering program. Try to express your definition in terms which are operational ("A student should be able to . . .") and which can be assessed (observable). The attached list of verbs may be helpful.

2) How would you evaluate a student's "contextual competency"? For example, what types of evidence would a student provide in order to demonstrate his or her level of competency?

3) When and where (e.g., in what courses) in the academic program could such evidence be collected?

Questionnaire Number ____________

Contextual Competence and the Curriculum

4) Select the response which best describes your opinion of how students **would best** develop contextual competence in the courses in the undergraduate curriculum (please select one).

______ Students would best develop contextual competence through coursework in engineering.

______ Students would best develop contextual competence through coursework in BOTH engineering and in the humanities and social sciences, but primarily through coursework in engineering.

______ Students would best develop contextual competence through coursework in BOTH engineering and in the humanities and social sciences, but primarily through coursework in the humanities and social sciences.

______ Students would best develop contextual competence through coursework in the humanities and social sciences.

______ I do not believe that contextual competence is developed through coursework.

______ Other (please specify):

5) Overall Level of Emphasis – Undergraduate Chemical Engineering Courses in the Curriculum

a) Please select the response which best describes your opinion of the **overall level of emphasis** on the development of contextual competence in the required undergraduate **chemical engineering** courses (please select one).

______ There is no emphasis on the development of contextual competence.

______ There is some emphasis on the development of contextual competence, but the level of emphasis is inadequate.

______ There is some emphasis on the development of contextual competence, and the level of emphasis is adequate.

______ There is too much emphasis on the development of contextual competence.

______ Other (please specify):

b) In your opinion, the **overall level of emphasis** on the development of contextual competence in the required undergraduate **chemical engineering** courses **should be** (please select one):

______ less than the current emphasis.

______ the same as the current emphasis.

______ more than the current emphasis.

______ no opinion

Comments:

6) Overall Level of Emphasis – Courses in the Humanities and Social Sciences Taken by Engineering Students

a) Please select the response which best describes your opinion of the **overall level of emphasis** on the development of contextual competence in the **courses in the humanities and social sciences** taken by engineering students (please select one).

______ There is no emphasis on the development of contextual competence.

______ There is some emphasis on the development of contextual competence, but the level of emphasis is inadequate.

______ There is some emphasis on the development of contextual competence, and the level of emphasis is adequate.

______ There is too much emphasis on the development of contextual competence.

______ Other (please specify):

b) In your opinion, the **overall level of emphasis** on the development of contextual competence in the courses in the **humanities and social sciences** taken by engineering students **should be** (please select one):

______ less than the current emphasis.	______ the same as the current emphasis.	______ more than the current emphasis.	______ no opinion

Comments:

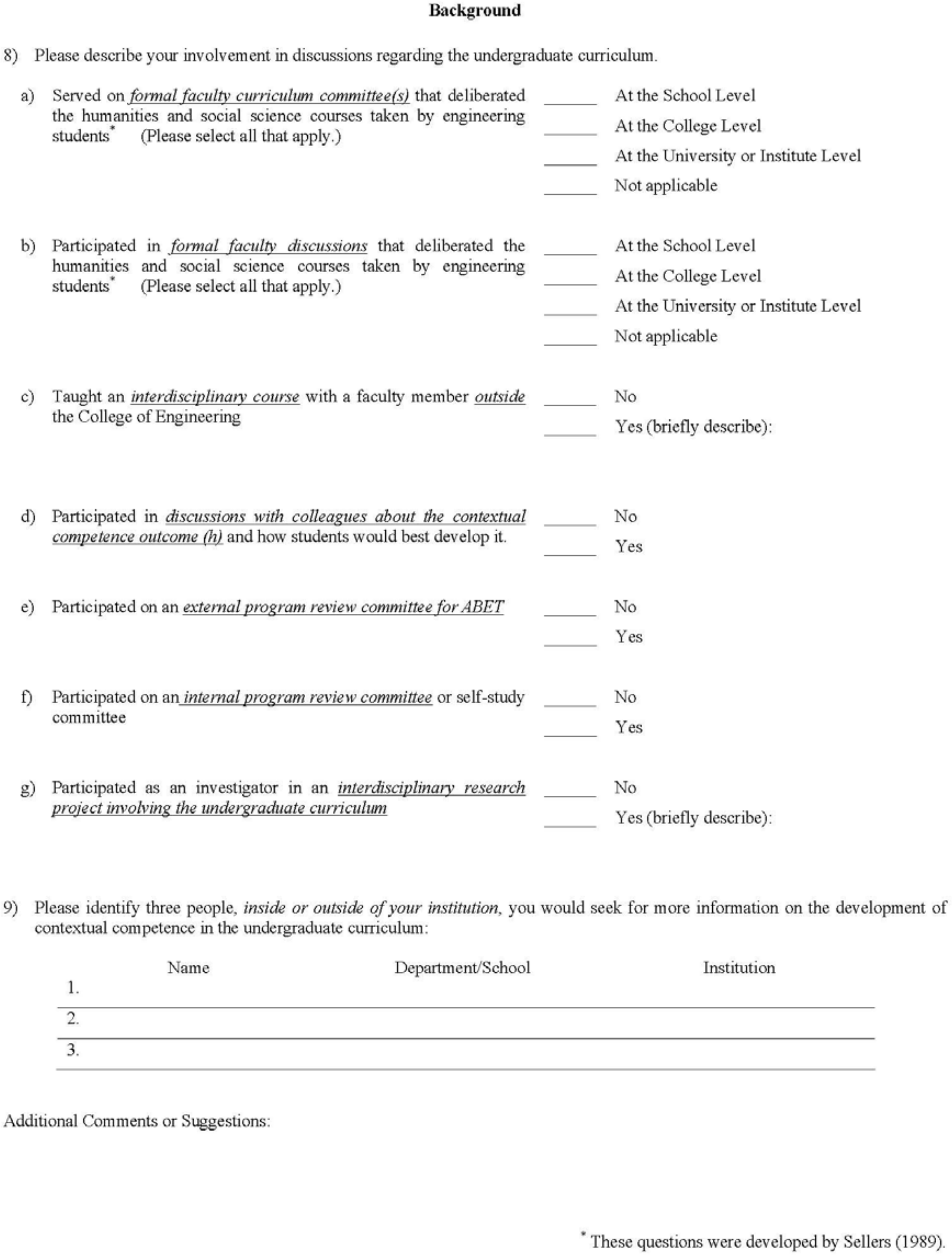
7) It is possible that contextual competence is addressed, directly or indirectly, throughout the courses in the undergraduate chemical engineering curriculum. Based on your understanding of the courses in the undergraduate curriculum, use the following scale to describe the extent to which the development of contextual competence is emphasized in each course. *Please provide your best response for each course, even for those courses you do not teach.*

Scale

0 = Not an objective of this course
1 = Not a formal objective, but addressed informally through discussion, examples or exercises
2 = A minor objective of this course
3 = A major objective of this course
? = Not familiar enough with the course to make an assessment

Please circle one for each course.

	Emphasis on Contextual Competence in the Course				
Course Number and Title	Not an Objective	Not Addressed Formally	Minor Objective	Major Objective	Not Familiar
ChBE 2100 Chemical Process Principles	0	1	2	3	?
ChBE 2110 Chem Eng Thermodynamics I	0	1	2	3	?
ChBE 2120 Numerical Methods	0	1	2	3	?
ChBE 3110 Chem Eng Thermodynamics II	0	1	2	3	?
ChBE 3200 Transport Processes I	0	1	2	3	?
ChBE 3210 Transport Processes II	0	1	2	3	?
ChBE 4300 Kinetics and Reactor Design	0	1	2	3	?
ChBE 3225 Separation Processes	0	1	2	3	?
ChBE 4400 Process Control	0	1	2	3	?
ChBE 4515 Process Safety	0	1	2	3	?
ChBE 4200 Transport Phenomena/Unit Ops Lab	0	1	2	3	?
ChBE 4505 Process Design and Economics	0	1	2	3	?



Background

8) Please describe your involvement in discussions regarding the undergraduate curriculum.

a) Served on *formal faculty curriculum committee(s)* that deliberated the humanities and social science courses taken by engineering students[*] (Please select all that apply.)

______ At the School Level
______ At the College Level
______ At the University or Institute Level
______ Not applicable

b) Participated in *formal faculty discussions* that deliberated the humanities and social science courses taken by engineering students[*] (Please select all that apply.)

______ At the School Level
______ At the College Level
______ At the University or Institute Level
______ Not applicable

c) Taught an *interdisciplinary course* with a faculty member *outside* the College of Engineering

______ No
______ Yes (briefly describe):

d) Participated in *discussions with colleagues about the contextual competence outcome (h)* and how students would best develop it.

______ No
______ Yes

e) Participated on an *external program review committee for ABET*

______ No
______ Yes

f) Participated on an *internal program review committee* or self-study committee

______ No
______ Yes

g) Participated as an investigator in an *interdisciplinary research project involving the undergraduate curriculum*

______ No
______ Yes (briefly describe):

9) Please identify three people, *inside or outside of your institution*, you would seek for more information on the development of contextual competence in the undergraduate curriculum:

	Name	Department/School	Institution
1.			
2.			
3.			

Additional Comments or Suggestions:

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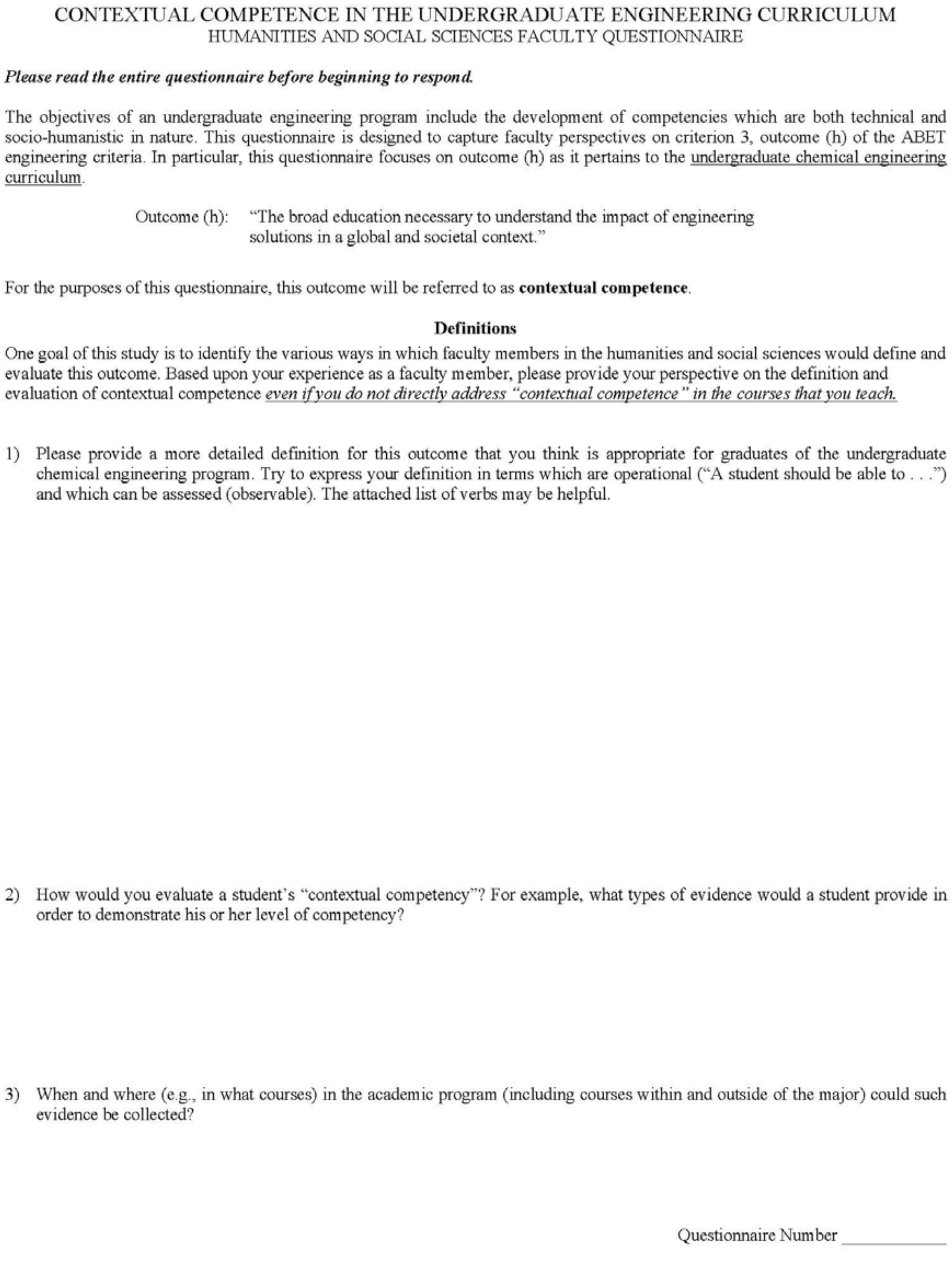
[*] These questions were developed by Sellers (1989).



CONTEXTUAL COMPETENCE IN THE UNDERGRADUATE ENGINEERING CURRICULUM

HUMANITIES AND SOCIAL SCIENCES FACULTY QUESTIONNAIRE

Please read the entire questionnaire before beginning to respond.

The objectives of an undergraduate engineering program include the development of competencies which are both technical and socio-humanistic in nature. This questionnaire is designed to capture faculty perspectives on criterion 3, outcome (h) of the ABET engineering criteria. In particular, this questionnaire focuses on outcome (h) as it pertains to the undergraduate chemical engineering curriculum.

Outcome (h): "The broad education necessary to understand the impact of engineering solutions in a global and societal context."

For the purposes of this questionnaire, this outcome will be referred to as **contextual competence**.

Definitions

One goal of this study is to identify the various ways in which faculty members in the humanities and social sciences would define and evaluate this outcome. Based upon your experience as a faculty member, please provide your perspective on the definition and evaluation of contextual competence *even if you do not directly address "contextual competence" in the courses that you teach.*

1) Please provide a more detailed definition for this outcome that you think is appropriate for graduates of the undergraduate chemical engineering program. Try to express your definition in terms which are operational ("A student should be able to . . .") and which can be assessed (observable). The attached list of verbs may be helpful.

2) How would you evaluate a student's "contextual competency"? For example, what types of evidence would a student provide in order to demonstrate his or her level of competency?

3) When and where (e.g., in what courses) in the academic program (including courses within and outside of the major) could such evidence be collected?

Questionnaire Number ____________

Contextual Competence and the Curriculum

4) Select the response which best describes your opinion of how students **would best** develop contextual competence in the courses in the undergraduate curriculum (please select one).

______ Students would best develop contextual competence through coursework in engineering.

______ Students would best develop contextual competence through coursework in BOTH engineering and in the humanities and social sciences, but primarily through coursework in engineering.

______ Students would best develop contextual competence through coursework in BOTH engineering and in the humanities and social sciences, but primarily through coursework in the humanities and social sciences.

______ Students would best develop contextual competence through coursework in the humanities and social sciences.

______ I do not believe that contextual competence is developed through coursework.

______ Other (please specify):

5) Level of Emphasis – Courses Offered by Your School/Discipline Taken by Engineering Students

a) Please select the response which best describes your opinion of the overall **level of emphasis** on the development of contextual competence in the **courses offered by your school/discipline** to engineering students completing general education and elective requirements (please select one).

______ There is no emphasis on the development of contextual competence.

______ There is some emphasis on the development of contextual competence, but the level of emphasis is inadequate.

______ There is some emphasis on the development of contextual competence, and the level of emphasis is adequate.

______ There is too much emphasis on the development of contextual competence.

______ Other (please specify):

b) In your opinion, the overall **level of emphasis** on the development of contextual competence in **courses offered by your school/discipline** to students completing general education and elective requirements **should be** (please select one):

______ less than the current emphasis.

______ the same as the current emphasis.

______ more than the current emphasis.

______ no opinion

Comments:

6) Overall Level of Emphasis – Courses in the Humanities and Social Sciences Taken by Engineering Students

a) Please select the response which best describes your opinion of the **overall level of emphasis** on the development of contextual competence in the **courses in the humanities and social sciences** taken by engineering students completing general education and elective requirements (please select one).

______ There is no emphasis on the development of contextual competence.

______ There is some emphasis on the development of contextual competence, but the level of emphasis is inadequate.

______ There is some emphasis on the development of contextual competence, and the level of emphasis is adequate.

______ There is too much emphasis on the development of contextual competence.

______ Other (please specify):

b) In your opinion, the **overall level of emphasis** on the development of contextual competence in the courses in the **humanities and social sciences** taken by engineering students **should be** (please select one):

______ less than the current emphasis.
______ the same as the current emphasis.
______ more than the current emphasis.
______ no opinion

Comments:

7) Contextual competence may be addressed, directly or indirectly, in the humanities and social science courses taken by chemical engineering students when fulfilling the general education requirements of the Institute or the elective requirements of the chemical engineering degree program. This question is intended to **identify courses that would best contribute to the development of contextual competence** in engineering students.

Please **list those courses offered by your school/discipline** that would best promote the development of contextual competence, as you defined it in question #1. Indicate the extent to which the development of contextual competence is emphasized in each course. *Please provide your best response for each course, even for those courses you do not teach.*

Scale

1 = Not a formal objective, but addressed informally through discussion, examples or exercises
2 = A minor objective of this course, addressed formally in the content of course materials
3 = A major objective of this course, addressed formally in the content of course materials

Please list course numbers, titles and circle one of the options describing the level of emphasis on contextual competence for each course you list.

	Emphasis on Contextual Competence in the Course		
Course Number and Title	Not Addressed Formally	Minor Objective	Major Objective
	1	2	3
	1	2	3
	1	2	3
	1	2	3
	1	2	3
	1	2	3

Comments:

Background

8) Please describe your involvement in discussions regarding the undergraduate curriculum.

a) Served on *formal faculty curriculum committee(s)* that deliberated the humanities and social science courses taken by engineering students[*] (Please select all that apply.)

______ At the School Level
______ At the College Level
______ At the University or Institute Level
______ Not applicable

b) Participated in *formal faculty discussions* that deliberated the humanities and social science courses taken by engineering students[*] (Please select all that apply.)

______ At the School Level
______ At the College Level
______ At the University or Institute Level
______ Not applicable

c) Taught an *interdisciplinary course* with a faculty member in the College of Engineering

______ No
______ Yes (briefly describe):

d) Participated *in discussions with colleagues about the contextual competence outcome (h)* and how students would best develop it.

______ No
______ Yes

e) Participated as an investigator in an *interdisciplinary research project* involving the undergraduate engineering curriculum

______ No
______ Yes (briefly describe):

f) Participated in discussions with engineering faculty regarding the socio-humanistic *objectives of an engineering course(s)*

______ No
______ Yes (briefly describe):

9) Please identify three people, *inside or outside of your institution*, you would seek for more information on the development of contextual competence in the undergraduate curriculum:

	Name	Department/School	Institution
1.			
2.			
3.			

Additional Comments or Suggestions:

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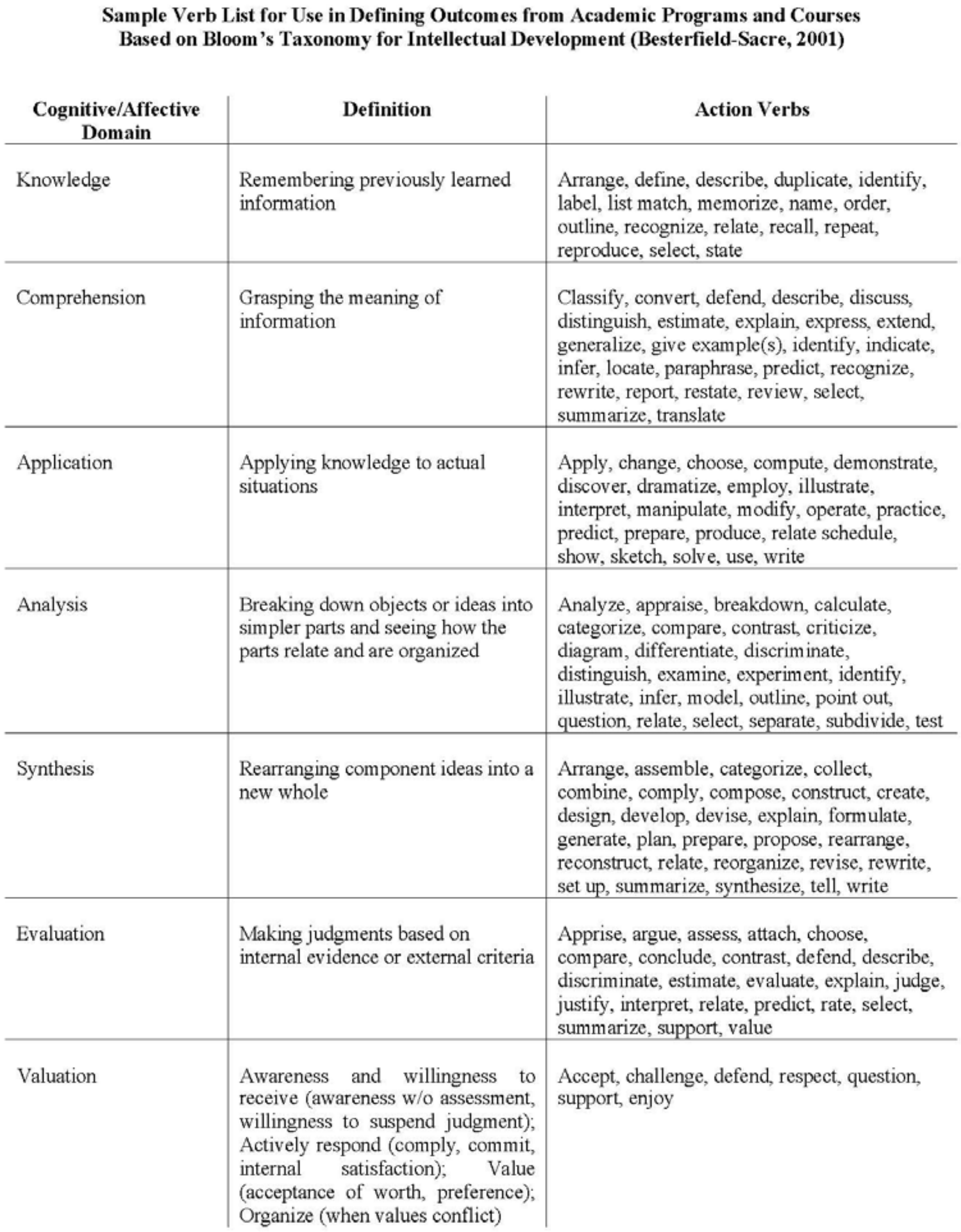
[*] These questions were developed by Sellers (1989).



Sample Verb List for Use in Defining Outcomes from Academic Programs and Courses
Based on Bloom's Taxonomy for Intellectual Development (Besterfield-Sacre, 2001)

Cognitive/Affective Domain	Definition	Action Verbs
Knowledge	Remembering previously learned information	Arrange, define, describe, duplicate, identify, label, list match, memorize, name, order, outline, recognize, relate, recall, repeat, reproduce, select, state
Comprehension	Grasping the meaning of information	Classify, convert, defend, describe, discuss, distinguish, estimate, explain, express, extend, generalize, give example(s), identify, indicate, infer, locate, paraphrase, predict, recognize, rewrite, report, restate, review, select, summarize, translate
Application	Applying knowledge to actual situations	Apply, change, choose, compute, demonstrate, discover, dramatize, employ, illustrate, interpret, manipulate, modify, operate, practice, predict, prepare, produce, relate schedule, show, sketch, solve, use, write
Analysis	Breaking down objects or ideas into simpler parts and seeing how the parts relate and are organized	Analyze, appraise, breakdown, calculate, categorize, compare, contrast, criticize, diagram, differentiate, discriminate, distinguish, examine, experiment, identify, illustrate, infer, model, outline, point out, question, relate, select, separate, subdivide, test
Synthesis	Rearranging component ideas into a new whole	Arrange, assemble, categorize, collect, combine, comply, compose, construct, create, design, develop, devise, explain, formulate, generate, plan, prepare, propose, rearrange, reconstruct, relate, reorganize, revise, rewrite, set up, summarize, synthesize, tell, write
Evaluation	Making judgments based on internal evidence or external criteria	Apprise, argue, assess, attach, choose, compare, conclude, contrast, defend, describe, discriminate, estimate, evaluate, explain, judge, justify, interpret, relate, predict, rate, select, summarize, support, value
Valuation	Awareness and willingness to receive (awareness w/o assessment, willingness to suspend judgment); Actively respond (comply, commit, internal satisfaction); Value (acceptance of worth, preference); Organize (when values conflict)	Accept, challenge, defend, respect, question, support, enjoy

Cover Letter for Questionnaire 2

Date

From: Carol Carmichael
To: [Faculty Name]
Subject: Questionnaire #2, Final Input
Study Title: Constructing the Concept of Contextual Competence in an Undergraduate Engineering Curriculum

I hope you have had an enjoyable and productive summer. Thank you once more for agreeing to participate in my dissertation study. I am pleased to report that the responses to the questionnaire last Spring, combined with the information I am requesting from you now, will be sufficient for completion of my dissertation study. This final questionnaire replaces the more time-consuming interviews and analyses of course materials proposed at the beginning of the study (as indicated on your consent form).

In the attached Questionnaire #2, I am asking you to review a series of attribute statements for the definition of contextual competence. These attributes were identified by faculty members in chemical engineering and in the humanities and social sciences at Georgia Tech. Completion of Questionnaire #2 should take no more than 30 minutes.

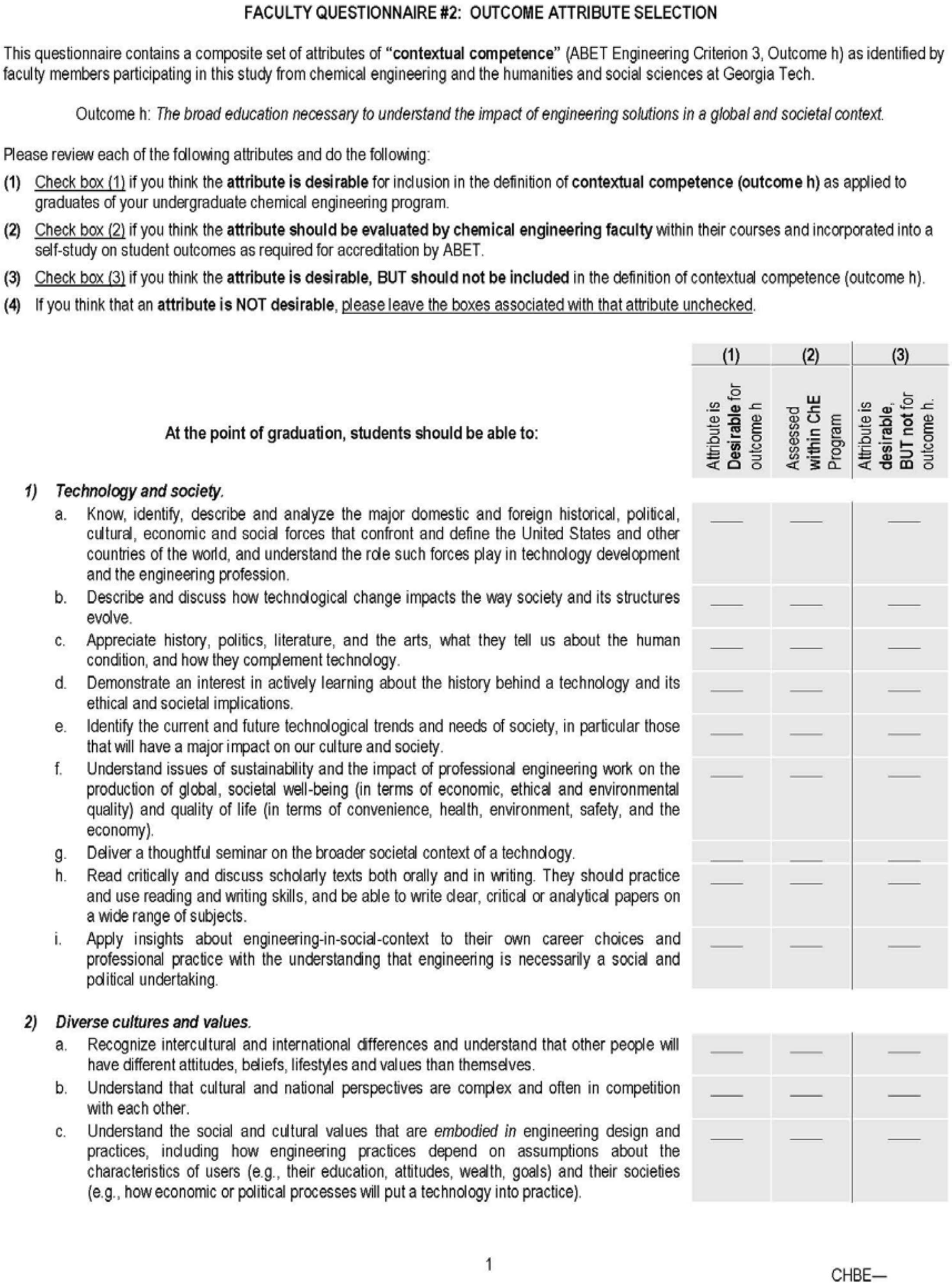
The purpose of Questionnaire #2 is to identify those attributes you think:

- Are desirable for inclusion in the definition of contextual competence (outcome h) as applied to graduates of your undergraduate chemical engineering program.
- Should be evaluated by chemical engineering faculty within their courses and incorporated into a self-study on student outcomes as required for accreditation by ABET.
- Are desirable, BUT should not be included in the definition of contextual competence (outcome h).
- Are NOT desirable.

Please complete the questionnaire **by August 23rd.**

Please **return the completed questionnaire to: Departmental Secretary**

Questions? Please contact me at: carol.carmichael@marc.gatech.edu, or 404-894-5676.



FACULTY QUESTIONNAIRE #2: OUTCOME ATTRIBUTE SELECTION

This questionnaire contains a composite set of attributes of **"contextual competence"** (ABET Engineering Criterion 3, Outcome h) as identified by faculty members participating in this study from chemical engineering and the humanities and social sciences at Georgia Tech.

> Outcome h: *The broad education necessary to understand the impact of engineering solutions in a global and societal context.*

Please review each of the following attributes and do the following:

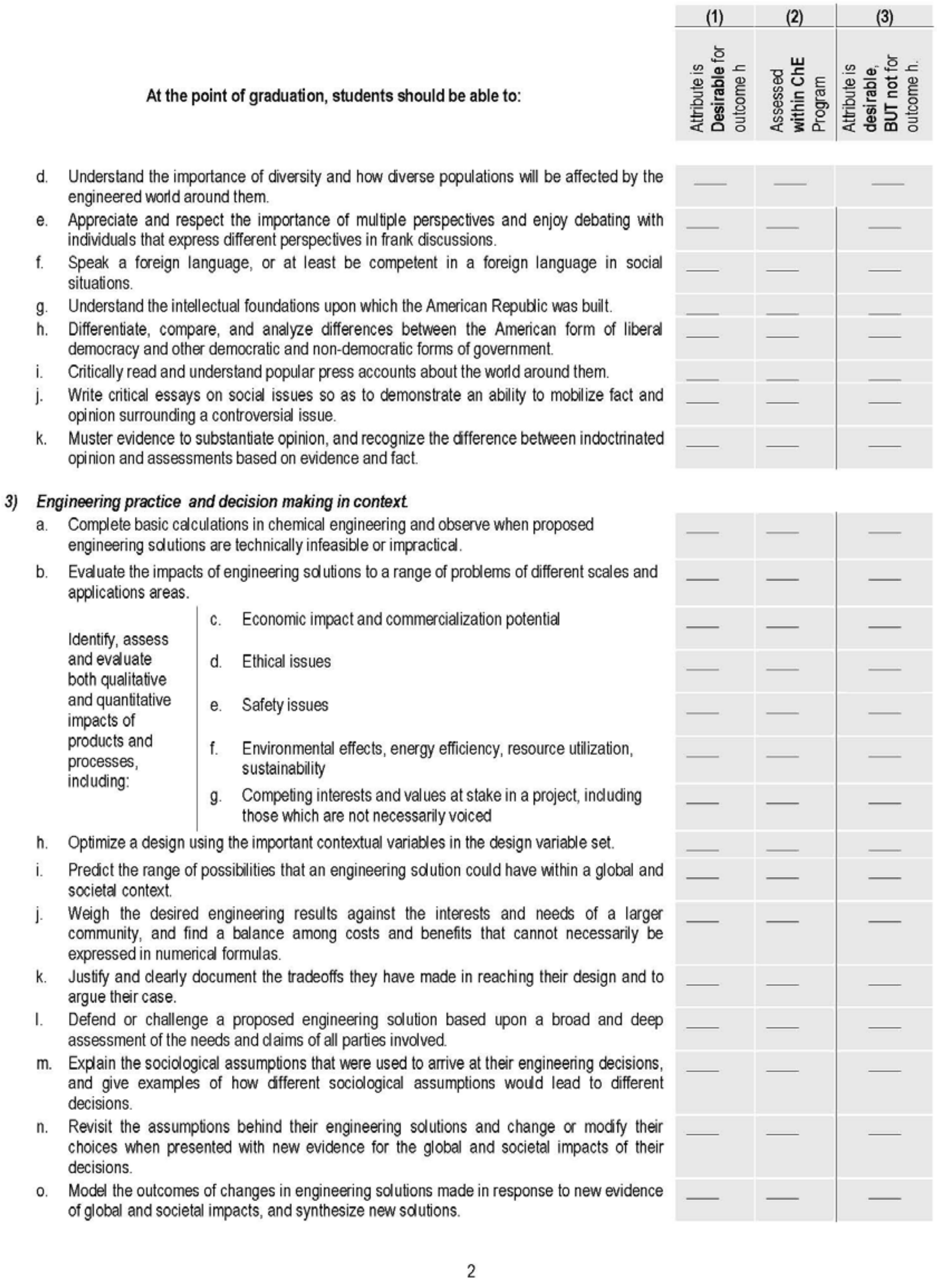
(1) Check box (1) if you think the **attribute is desirable** for inclusion in the definition of **contextual competence (outcome h)** as applied to graduates of your undergraduate chemical engineering program.

(2) Check box (2) if you think the **attribute should be evaluated by chemical engineering faculty** within their courses and incorporated into a self-study on student outcomes as required for accreditation by ABET.

(3) Check box (3) if you think the **attribute is desirable, BUT should not be included** in the definition of contextual competence (outcome h).

(4) If you think that an **attribute is NOT desirable**, please leave the boxes associated with that attribute unchecked.

At the point of graduation, students should be able to:	(1) Attribute is **Desirable** for outcome h	(2) Assessed **within ChE** Program	(3) Attribute is **desirable, BUT not** for outcome h.
1) Technology and society.			
a. Know, identify, describe and analyze the major domestic and foreign historical, political, cultural, economic and social forces that confront and define the United States and other countries of the world, and understand the role such forces play in technology development and the engineering profession.	____	____	____
b. Describe and discuss how technological change impacts the way society and its structures evolve.	____	____	____
c. Appreciate history, politics, literature, and the arts, what they tell us about the human condition, and how they complement technology.	____	____	____
d. Demonstrate an interest in actively learning about the history behind a technology and its ethical and societal implications.	____	____	____
e. Identify the current and future technological trends and needs of society, in particular those that will have a major impact on our culture and society.	____	____	____
f. Understand issues of sustainability and the impact of professional engineering work on the production of global, societal well-being (in terms of economic, ethical and environmental quality) and quality of life (in terms of convenience, health, environment, safety, and the economy).	____	____	____
g. Deliver a thoughtful seminar on the broader societal context of a technology.	____	____	____
h. Read critically and discuss scholarly texts both orally and in writing. They should practice and use reading and writing skills, and be able to write clear, critical or analytical papers on a wide range of subjects.	____	____	____
i. Apply insights about engineering-in-social-context to their own career choices and professional practice with the understanding that engineering is necessarily a social and political undertaking.	____	____	____
2) Diverse cultures and values.			
a. Recognize intercultural and international differences and understand that other people will have different attitudes, beliefs, lifestyles and values than themselves.	____	____	____
b. Understand that cultural and national perspectives are complex and often in competition with each other.	____	____	____
c. Understand the social and cultural values that are *embodied in* engineering design and practices, including how engineering practices depend on assumptions about the characteristics of users (e.g., their education, attitudes, wealth, goals) and their societies (e.g., how economic or political processes will put a technology into practice).	____	____	____



	At the point of graduation, students should be able to:	(1) Attribute is **Desirable** for outcome h	(2) Assessed **within ChE** Program	(3) Attribute is **desirable, BUT not for** outcome h.
d.	Understand the importance of diversity and how diverse populations will be affected by the engineered world around them.	____	____	____
e.	Appreciate and respect the importance of multiple perspectives and enjoy debating with individuals that express different perspectives in frank discussions.	____	____	____
f.	Speak a foreign language, or at least be competent in a foreign language in social situations.	____	____	____
g.	Understand the intellectual foundations upon which the American Republic was built.	____	____	____
h.	Differentiate, compare, and analyze differences between the American form of liberal democracy and other democratic and non-democratic forms of government.	____	____	____
i.	Critically read and understand popular press accounts about the world around them.	____	____	____
j.	Write critical essays on social issues so as to demonstrate an ability to mobilize fact and opinion surrounding a controversial issue.	____	____	____
k.	Muster evidence to substantiate opinion, and recognize the difference between indoctrinated opinion and assessments based on evidence and fact.	____	____	____
3)	***Engineering practice and decision making in context.***			
a.	Complete basic calculations in chemical engineering and observe when proposed engineering solutions are technically infeasible or impractical.	____	____	____
b.	Evaluate the impacts of engineering solutions to a range of problems of different scales and applications areas.	____	____	____
	Identify, assess and evaluate both qualitative and quantitative impacts of products and processes, including:			
c.	Economic impact and commercialization potential	____	____	____
d.	Ethical issues	____	____	____
e.	Safety issues	____	____	____
f.	Environmental effects, energy efficiency, resource utilization, sustainability	____	____	____
g.	Competing interests and values at stake in a project, including those which are not necessarily voiced	____	____	____
h.	Optimize a design using the important contextual variables in the design variable set.	____	____	____
i.	Predict the range of possibilities that an engineering solution could have within a global and societal context.	____	____	____
j.	Weigh the desired engineering results against the interests and needs of a larger community, and find a balance among costs and benefits that cannot necessarily be expressed in numerical formulas.	____	____	____
k.	Justify and clearly document the tradeoffs they have made in reaching their design and to argue their case.	____	____	____
l.	Defend or challenge a proposed engineering solution based upon a broad and deep assessment of the needs and claims of all parties involved.	____	____	____
m.	Explain the sociological assumptions that were used to arrive at their engineering decisions, and give examples of how different sociological assumptions would lead to different decisions.	____	____	____
n.	Revisit the assumptions behind their engineering solutions and change or modify their choices when presented with new evidence for the global and societal impacts of their decisions.	____	____	____
o.	Model the outcomes of changes in engineering solutions made in response to new evidence of global and societal impacts, and synthesize new solutions.	____	____	____

	At the point of graduation, students should be able to:	(1) Attribute is **Desirable** for outcome h	(2) Assessed **within ChE** Program	(3) Attribute is **desirable, BUT not** for outcome h.
p.	Effectively communicate engineering decisions, concerns and observations to appropriate individuals and groups.	____	____	____
q.	Know and comprehend the basic steps toward strategic planning and decision making, as well as the rules of logic.	____	____	____
	Demonstrate decision making skills where they:			
r.	Effectively synthesize and analyze knowledge and apply it to a decision context.	____	____	____
s.	Evaluate the outcomes of their decision.	____	____	____
t.	Implement their decisions on an individual basis and by working in groups in both face-to-face and electronic group contexts.	____	____	____
4)	***Economics and business***			
a.	Know and understand micro- and macroeconomics, how economists approach decision making, and how decisions made in the technology arena play out in the economic environment of a firm or organization and in the global economy.	____	____	____
b.	Analyze, from an economist's mind set, macro policy issues at the national/regional level, economic decisions made at the firm level, and economic impacts of proposed engineering solutions (including performance of risk assessment and cost-benefit analyses).	____	____	____
c.	Assess the societal benefits and detriments associated with outsourcing and offshore manufacturing.	____	____	____
d.	Demonstrate comprehension of redistribution of resources, allocation of scarce resources, and cultural impacts resulting from engineering projects.	____	____	____
e.	Properly allocate scarce resources and determine price quantity combinations that ensure the viability of the organization and meet the demands of society.	____	____	____
f.	Judge engineering solutions to a given problem in a context where economic and business, sociological, historical, ethical, environmental and political criteria are at least as important as the science and engineering criteria.	____	____	____
g.	Anticipate how social forces (economic and business, sociological, historical, ethical, environmental and political) will affect the implementation, success, and acceptance of engineering solutions.	____	____	____
h.	Judge whether or not engineering solutions should be introduced, recalled, or otherwise adapted.	____	____	____
i.	Respect intercultural and international differences in dealing with business partners. They should be able to generate business proposals and evaluate business situations based on background knowledge of such differences.	____	____	____
5)	***Safety***			
a.	Assess the risks and safety issues associated with any chemical process, product, or facility in the broader societal context, and raise the safety issues as questions for discussion.	____	____	____
b.	Discuss the concept of "inherent risk".	____	____	____
c.	Assess the balance between the need for public safety and the need for the new technology.	____	____	____
d.	Recognize toxic or ecologically persistent materials if these are involved in a proposed process, and be able to predict if such materials are likely to be formed under the proposed conditions.	____	____	____
e.	Design or synthesize an appropriate safety or containment system for any chemical process or product.	____	____	____
f.	Assess safe protocols and write these protocols into the procedures that will be used by personnel who are working with the process equipment.	____	____	____
g.	Explain the role of the engineer in public safety at multiple levels: worker and personal safety; local community safety; societal safety.	____	____	____

At the point of graduation, students should be able to:	**(1)** Attribute is **Desirable** for outcome h	**(2)** Assessed **within ChE** Program	**(3)** Attribute is **desirable, BUT not for** outcome h.
6) Human behavior and technology			
a. Discriminate among competing theories, explanations, and ideologies for human behavior and culture, and be able to describe competing explanations for social behavior.	____	____	____
b. Challenge their own beliefs about human behavior and the values, beliefs, and attitudes that may underlie that behavior.	____	____	____
c. Identify the "human factors" (e.g., human psychology, human errors or imperfection, uncertainties created by human and their interactions, and communication) involved in development of an engineering solution.	____	____	____
d. Assess the impact of human factors on the effectiveness of an engineering solution, and the ability of people to make use of the solution.	____	____	____
7) Ethics and the engineering profession			
a. Recognize their role as "good citizens" in society and understand the accompanying responsibilities and duties.	____	____	____
b. Work as responsible professionals, actively acquiring specific technical knowledge about the aspects of the chemical engineering profession that are most likely to directly impact society.	____	____	____
c. Articulate the fundamental principles of ethical reasoning.	____	____	____
d. Evaluate science and technology based activities and outcomes from ethical perspectives.	____	____	____
e. Analyze and evaluate historical and/or hypothetical case studies, indicating what they might do in a given situation and why.	____	____	____
f. Understand the need for ethical professional behavior, exhibit critical thinking when presented with an ethical situation, and be willing to make engineering judgments and decisions that are ethically correct and consistent with accepted professional practice.	____	____	____
g. Comprehend the basic factors associated with sound leadership and ethical behavior and be able to differentiate between leadership and management.	____	____	____
Distinguish ethical and social considerations from matters of expediency or self interest: h. Assess the relative merits of expedience and exercise due diligence.	____	____	____
i. Defend a position on the side of due diligence even when this position may be contrary to the wishes of his/her superiors.	____	____	____
j. Resolutely and passionately support engineering solutions that are fundamentally correct and socially beneficial, even if such solutions are not politically popular.	____	____	____

8) Reflection on the Study Process

a. Did completion of the two questionnaires in this study change your understanding and definition of the concept of "contextual competence" (ABET Criterion 3, Outcome h)? ____ Yes ____ No

b. Would you use the results of this study in your undergraduate engineering program (e.g., the desirable attributes, the types of evidence needed for evaluating students' level of achievement, the courses in which such evaluations would take place, etc.)? ____ Yes ____ No

c. Comments:

Appendix E. Detailed Data Analysis Procedures

The following data analysis procedures are intended to guide researchers interested in conducting a similar study.

Transcript analysis detail

The transcript data were sorted by subject, and the subject data were subsequently organized into the two areas, humanities and social sciences. The core curriculum requirements of the University System of Georgia and Georgia Tech were used to assign courses into the humanities and social science areas. The enrollment frequencies were summed across all courses in each subject, and then across all subjects in the humanities and social science areas respectively.

Questionnaire Format

Each questionnaire was formatted in booklet form to fit on one 11” x 17” sheet of cover stock paper. The sample verb list was printed on yellow cover stock paper.

Faculty Background in Curriculum Activities

New information was collected on the participation of the CHE and HSS faculty in curriculum related activities (Questionnaire 1, item 8), and the individuals they would contact for more information on the development of contextual competence in the undergraduate curriculum (Questionnaire 1, item 9). For each faculty group**,** response frequencies were counted and percentages calculated for each response category.

The respondents identified contacts by name and by departmental and institutional affiliation. This information was used to determine the extent to which the respondents would seek colleagues in their own disciplines or from their own institution for knowledge about contextual competence. The contact data were analyzed by departmental and institutional affiliation to determine, for each faculty group, the proportion of contacts from engineering, humanities and social sciences, or other disciplines, and the proportion of contacts located at Georgia Tech or other institutions. The contact data were also analyzed by faculty respondent to determine the proportion of respondents who identified (1) at least one contact at any institution in engineering, humanities and social sciences, or other disciplines; (2) at least one contact at Georgia Tech in engineering, humanities and social sciences, or other disciplines; (3) contacts only in engineering, humanities and social sciences, or other disciplines; and (4) contacts located only at other institutions.

Research Question 1: Definition of Contextual Competence

> How do faculty members in engineering and in the humanities and social sciences define contextual competence?

Two related sources of data were used to describe how faculty members defined contextual competence. The first group of data was drawn from the CHE and HSS faculty responses to Questionnaire 1, item 1, an open-ended item which asked the respondents to provide a more detailed definition of contextual competence that they thought was appropriate for graduates of the undergraduate chemical engineering program. One result of the analysis of Questionnaire 1, item 1, was a list of outcome attributes identified by the respondents for the definition of contextual competence. These outcome attributes were transformed into checklist items for Questionnaire 2, the second source of data used to address this research question. Questionnaire 2 resulted in three lists that were used to characterize the definition of contextual competence: one list contained those outcome attributes the CHE faculty selected for inclusion in the definition of contextual competence, a second contained those outcome attributes they selected for the definition and to assess as part of an ABET self-study, and a third contained those outcome attributes they thought were desirable, but not for the definition of contextual competence.

Procedures for Questionnaire 1, item 1. Responses were analyzed using a comparative technique described by Merriam (Merriam, 1988). The responses to item 1 for both CHE and HSS faculty were transcribed into Microsoft-Word^{TM} documents. The definitions were read several times and a list of topics mentioned in each response was generated. The topics for all responses were subsequently sorted and combined into subthemes, and then themes for use in coding the responses. The definitions were then parsed into attribute fragments comprising distinct competencies that could be interpreted “in the absence of any additional information other than a broad understanding of the context” of the educational objective (Merriam, 1988, p. 132). The attribute fragments were coded by theme and rated according to Bloom’s taxonomy of intellectual development. The purpose of coding and sorting the attribute fragments by theme and Bloom’s level of intellectual development was to aid in identifying similar outcome attributes identified by different respondents. The researcher used an outcome attribute matrix for contextual competence (ABET, outcome h) developed by Besterfield-Sacre (2000) as an interpretive guide (Besterfield-Sacre, Shulman et al., 2000).

Concerned that engineering faculty were placing more emphasis on the “continuous improvement” aspects of the academic plan than on examining the *meaning* of the 11 ABET learning outcomes, Besterfield-Sacre and her colleagues developed hypothetical definitions of the outcomes based on the literature and their experience, and then refined the definitions through interviews with faculty and practitioners (Besterfield-Sacre, Shulman et al., 2000; Besterfield-Sacre, Shuman et al., 2000). The outcome definitions were developed by a multidisciplinary team with experience in evaluation and assessment methodologies, engineering ethics, design, communications, and classroom assessment techniques. The outcome definitions are specific descriptions of demonstrable competencies, presented in a matrix that organizes each attribute of the outcome according to Bloom's taxonomy of intellectual development (Bloom & Krathwohl, 1956). The authors encountered "minimal controversy" in defining many of the outcomes, but definition of two outcomes ("knowledge of contemporary issues" and "a broad education necessary for understanding the impact of engineering solutions in a societal and global context") proved particularly challenging because of the wide range of definitions that may be assigned to them (Besterfield-Sacre, Shuman et al., 2000, p. 103).

While the authors intended that their definitions be used to facilitate discussion among faculty about the ABET outcomes (Besterfield-Sacre, Shuman et al., 2000, p. 102), they demonstrated the use of the outcome/attribute approach for probing student outcomes in a previous study (Besterfield-Sacre, Atman, & Shuman, 1997). The complete outcome attribute matrix used in this study was obtained from authors' project website at the University of Pittsburgh: http://www.engr.pitt.edu/~ec2000/outcomes_html/MBS-cja-global-h-6-8.htm.

Definitions	**Knowledge**	**Comprehension**	**Application** →
Outcome Element **Understand the impact of engineering solutions in a *global* context** Global - meaning to cross cultures and societies, example areas of impact include, but not limited to, environmental, political, and economic.	• Can define key terms associated with understanding global issues. • Lists the steps in a method for identifying impacts of an engineering solution that crosses cultures or societies. • Can name sources of global impact knowledge. • Describes how nations and peoples around the globe are related. • Can recall the impacts of several engineering solutions, recent and historical, and their anticipated and unanticipated impacts • Student can identify a variety of types of impacts for a engineering solution. • Can identify criteria to be considered when an engineering solution has a global presence.	• Can describe situations where society has become more global. • Can explain an illustration of how modern technologies have had a global impact. • Can classify types of impacts an engineering solution in a global context. • Can recognize examples where solving one engineering problem led to the development of other engineering-related problems (ex. development of nuclear energy to reduce depletion of oil results in increased nuclear waste; development of antibiotics to help reduce bacterial infections results in an evolution of more resistant strains of bacteria)	• Can identify potential impacts, both short and long term, of an engineering solution currently being proposed. • Uses knowledge about the interrelationships of peoples and environments around globe to identify impacts of engineering solutions. • Identifies the relevant groups of people and environmental systems that need to be considered when evaluating an engineering solution.
Analysis	**Synthesis**	**Evaluation**	**Valuation**
• Appraises the actual impacts of an engineering solution into the appropriate impacts	• Summarizes the interrelated aspects of engineering solutions • Incorporates gained knowledge of potential and actual impacts into the design process of an engineer.	• Can assess conflicting / competing tradeoffs in order to make informed decisions about engineering solutions. • Judges the acceptability of the impacts of an engineering solution	• Respects the historical aspects of engineering solutions and their impacts. • Actively seeks knowledge of the world events which his/her engineering activity likely affects

Definitions	**Knowledge**	**Comprehension**	**Application** →
Outcome Element **Understand the impact of engineering solutions in a *societal* context** Societal – meaning issues associated with the groups of people and their beliefs, practices and needs	• Can describe the key features characterizing an individual perspective • Can identify a variety of practices, methods that others use • Can define key terms associated with understanding societal context • Can identify milestones in the evolution of current society, global society. • Can state differences in needs that result from diversity in society • Can state ways in which modern society is diverse. • Can identify different facets by which an engineered solution impacts modern society (e.g. aesthetics, religion, economics) • Can name sources of societal impact knowledge.	• Can identify and characterize different perspectives (beliefs, practices, etc.). • Can compare various practices/perspectives to identify similarities and differences. • Can describe the role that science, technology and engineering has played in the development of modern society. • Can describe how ideas and customs from other cultures have contributed to the engineering discipline and/or modern society.	• Can explain engineering conflicts in terms of differences of perspectives. • Can identify alternative mechanisms for solving a given problem. • Can use knowledge to identify impacts of an engineering solution • Can use knowledge of the ways in which ideas and customs from other cultures have contributed to modern life in order to support the identification of the impact of engineering solutions. • Can identify the key attributes of perspective different from their own.
Analysis	**Synthesis**	**Evaluation**	**Valuation**
• Appraises the failure of an engineering solution and investigate the role that unanticipated impacts played in the failure of the solution. • Can appraise alternative mechanisms for solving a conflict of a society's perspective.		• Can critically evaluate the strengths and weaknesses of their own perspectives • Can assess conflicting / competing tradeoffs in order to make informed decisions about engineering solutions. • Judges the acceptability of the impacts of an engineering solution	• Actively seeks knowledge of society in which his/her engineering activity is situated • Accepts perspectives different from their own.

The analysis involved the review and manipulation of a large amount of textual material, necessitating the use of Microsoft Excel^{TM} workbooks to manage and analyze the data. The attribute fragments were entered as records into a Microsoft Excel^{TM} worksheet for further analysis. Each attribute record included the code of the faculty member contributing the attribute fragment, the attribute statement, the assigned level of intellectual development, and the themes addressed by the attribute fragment. The attribute records could be sorted by faculty code, theme, or level of intellectual development. The attribute fragments were sorted by theme, copied to separate worksheets, and then sorted by Bloom's level of intellectual development. Each group of attribute fragments was reviewed, and similar attribute fragments identified by more than one participant were identified and combined into one outcome attribute statement. The outcome attributes were entered into a new worksheet, with each attribute record containing the new attribute statement (derived from the statements from related attribute fragments) and one of three codes identifying the composition of the group of faculty members that identified fragments to it: outcome attributes identified by engineering respondents only, by humanities and social sciences respondents only, or by respondents from both groups of faculty. The record files for the outcome attributes also contained the original list of faculty codes of CHE and/or HSS respondents who identified that particular attribute.

The outcome attribute data were sorted and response frequencies counted so as to identify patterns in the definitions of contextual competence for the CHE and HSS faculty groups. The following response frequencies were counted: the total number of outcome attributes reported overall, the number of outcome attributes reported in each thematic category, the number of outcome attributes identified by each source category, and the number of outcome attributes reported by each faculty group in each thematic category. The outcome attributes were sorted by CHE faculty code and the total number of outcome attributes identified by each CHE respondent were counted and cross tabulated by source category. Descriptive statistics (average, maximum, minimum, and mode) were calculated for the number of outcome attributes identified by all respondents in each faculty group. Finally, the outcome attributes were cross tabulated by theme and source category, and the table was used to analyze and interpret the definition of contextual competence as reported by CHE and HSS faculty.

Procedures for Questionnaire 2, Checklist items. The outcome attributes from Questionnaire 1 were used to develop the checklist items in Questionnaire 2. The CHE faculty responses to Questionnaire 2 were entered into a reporting matrix in Microsoft Excel™ containing, in the first three columns, the outcome attribute number (or the corresponding item number in Questionnaire 2), the attribute statement, and the source category code; and along the top row, the CHE faculty codes for the respondents. A separate worksheet was created for each of the checklist response categories:

1. The attribute is desirable for inclusion in the definition of contextual competence (outcome h) as applied to graduates of the undergraduate chemical engineering program;
2. The attribute should be evaluated by chemical engineering faculty within their courses and incorporated into a self-study on outcome (h) as required for accreditation by ABET;
3. The attribute is desirable, but should not be included in the definition of contextual competence (outcome h)

Response frequencies were counted for each outcome attribute to identify those outcome attributes selected by a majority (greater than 50%) of the CHE faculty for inclusion in the definition of contextual competence, for assessment under ABET, or as desirable but not for the definition of contextual competence. The outcome attributes selected by the majority of respondents in each response category were presented in table form. Another table was created for those attributes that were not selected by a majority of respondents in any category. Those attributes were presented, along with the percentage of respondents who selected them as desirable for the definition of contextual competence or desirable, but not for the definition of contextual competence.

Research Question 2: Courses in which Contextual Competence is Developed

> In which courses in the undergraduate curriculum do faculty members in engineering and in the humanities and social sciences believe contextual competence is best developed?

Data from Questionnaire 1, items 4 and 7 were used to answer this question.

Procedures for Questionnaire 1, item 4. Item 4 was a multiple choice question that asked the respondents to select from six response categories the response that best describes their opinion on how students would best develop contextual competence in courses in the undergraduate curriculum. The response categories were stated as follows:

1. Students would best develop contextual competence through coursework in engineering.
2. Students would best develop contextual competence through coursework in both engineering and in the humanities and social sciences, but primarily through coursework in engineering.
3. Students would best develop contextual competence through coursework in both engineering and in the humanities and social sciences, but primarily through coursework in the humanities and social sciences.
4. Students would best develop contextual competence through coursework in the humanities and social sciences.
5. I do not believe that contextual competence is developed through coursework.
6. Other (please specify)

Response frequencies for each response category were counted for CHE and HSS faculty groups and reported as percentages of all responses from each faculty group.

Procedures for Questionnaire 1, item 7, CHE faculty. The CHE respondents were asked to use a five-point scale to describe each of the 12 required undergraduate chemical engineering courses in terms of the extent to which the development of contextual competence was emphasized in them. Response frequencies were counted for each course for all respondents who indicated familiarity with the course. The results for each course were reported in bar graph form, indicating the percentage of respondents who described the course as having a major or minor emphasis on the development of contextual competence.

The data for the chemical engineering courses were examined further by splitting the responses for each course into two groups: respondents who had taught the course versus those who had not taught the course. The goal was to use the differences in reporting between the two groups as an indicator of misperceptions the faculty may have about the emphasis on contextual competence in chemical engineering courses taught by other colleagues in the department. Data from the Course Critique database were used to identify those respondents who had taught or not taught the courses since the year 2000. Response frequencies, modal responses and variation ratios were calculated for the subset of respondents who were familiar with the course, but had not taught the course between the years 2000 and 2004. The variation ratio, defined as the percentage of responses outside the modal category, excluded responses from faculty indicating they were "not familiar" with the course. The modal response of those respondents who had taught each course since 2000 was also determined. The results were presented in tabular form, with the courses listed in the recommended sequence in the curriculum.

Procedures for Questionnaire 1, item 7, HSS Faculty. The HSS respondents were asked to identify courses in their department or discipline that they thought would best promote the development of contextual competence in engineering students. They were asked to rate the level of emphasis on contextual competence in each course using a three-point scale (an informal objective, a minor objective, or a major objective). The responses were organized into three tables (one for each rating level) listing course titles and course numbers, organized by subject area.

Research Question 3: Level of Emphasis Placed on Contextual Competence

> Do faculty in engineering and in the humanities and social sciences believe that adequate emphasis is placed on contextual competence in courses in engineering or in courses in the humanities and social sciences?

Questionnaire 1, multiple-choice items 5 and 6 were designed to answer research question 3. In both versions of the questionnaire, the faculty were asked to give their opinion on the overall level of emphasis on contextual competence (what it is and what it should be) in the required chemical engineering courses (items 5a and 5b respectively) and in the courses in the humanities and social sciences taken by engineering students (items 6a and 6b respectively). Frequencies were counted for each response category for the respondents in the two faculty groups, and the results reported as percentages.

The responses were also analyzed for logical consistency between items 5a and 5b and between items 6a and 6b. This analysis was important for interpreting the results and to test the internal consistency of the questionnaire items. The possible combinations of responses between the two items were grouped into "expected combinations" and "mixed combinations." Mixed combinations were those that were inconsistent logically or otherwise required additional explanation from the respondent for interpretation. The combinations are displayed below:

Response Combinations for Questionnaire 1, Items 5a and 5b and Items 6a and 6b

	The level is:	The level should be:
Expected combinations	No emphasis	More
	Some emphasis, but inadequate	More
	Some emphasis, and adequate	Same
	Too much emphasis	Less

	Other	No opinion
	The level is:	The level should be:
Mixed combinations	No emphasis	Less, Same or No Opinion
	Some emphasis, but inadequate	Less, Same or No Opinion
	Some emphasis, and adequate	Less, More, or No Opinion
	Too much emphasis	Same, More, or No Opinion
	Other	More, Less, or Same

The response frequencies for each response combination for the CHE and HSS faculty were counted for Items 5a and 5b and 6a and 6b, and the results reported as percentages. The comments provided by the respondents were examined for insight into interpretation of the responses in the mixed combination category, and for response combinations including the "other" category.

Research Question 4: Evaluating Contextual Competence

> How would faculty members in engineering and in the humanities and social sciences evaluate student achievement of contextual competence? When and where (e.g., in what courses) in the academic program would they evaluate student achievement?

Questionnaire 1, items 2 and 3 were designed to address research question 4. The open-ended items were analyzed using a comparative technique described by Merriam (Merriam, 1988). The faculty responses for these items were more concise than those provided for item 1, and could be analyzed without the use of computer software. The results from the analysis of Questionnaire 2 were also used to address this research question; in particular, the list of those outcome attributes the CHE faculty would include in the definition of contextual competence and evaluate as part of a self-study as required for accreditation by ABET. The analysis of the Questionnaire 2 data was described in Research Question 1 of this chapter.

Procedure for Questionnaire 1, item 2. Item 2 asked the respondents to explain how they would evaluate a student's contextual competency and to describe the types of evidence a student would provide in order to demonstrate his or her level of competency. The responses to item 2 were read several times to generate a list of the types of evidence faculty would use as evidence for contextual competence (item 2). The responses were subsequently sorted by evidence type, and the response frequencies counted for each type of evidence. The results were reported as percentages of faculty identifying each type of evidence.

Procedure for Questionnaire 1, item 3. Item 3 asked the respondents to identify the courses in which they would collect evidence of a student's contextual competency. The responses were read several times to generate a list of courses or types of courses identified by respondents in each faculty group. The responses were sorted by course or course category, and the response frequencies counted for each course or course category. The results were reported in tabular form as percentages of faculty identifying each course or course category.

Research Question 5: Effect of the Protocol

> What effect does participation in the protocol have on how engineering faculty define contextual competence? Does the protocol provide useful information for faculty members interested in academic program improvement?

The effect of the two-questionnaire protocol was explored by examining the change in the definition of contextual competence from Questionnaire 1 to Questionnaire 2 for each CHE faculty respondent, and the nature of that change. The analysis also included faculty responses to two direct questions that asked if completion of the two questionnaires in the protocol changed their understanding and definition of the concept of contextual competence (Questionnaire 2, item 8a), and if they would use the results of the study in their undergraduate engineering program (Questionnaire 2, item 8b).

Change in definition of contextual competence. The change in the definition of contextual competence was defined as the difference between the number of outcome attributes selected in Questionnaire 2 and the number of outcome attributes identified in Questionnaire 1. The outcome attribute databases for Questionnaire 1 (item 1) and for Questionnaire 2 (checklist items) described in <u>Research Question 1</u>, were used to obtain the response frequencies for each CHE faculty respondent. Using the data in Questionnaire 1 and Questionnaire 2, the outcome attributes were sorted by CHE faculty code and response frequencies counted for the total number of outcome attributes identified and selected by each CHE participant and the total number of outcome attributes identified and selected, distributed by source category. The results were reported for each CHE participant in bar chart format. The change was described for the entire group using descriptive statistics (average, maximum, minimum, and median) for the outcome attributes added by the respondents from Questionnaire 1 to Questionnaire 2.

<u>Nature of the change.</u> The nature of the change was defined as the distribution of the outcome attributes added to the definition of contextual competence by source category (engineering only, HSS only, or both engineering and HSS). The data were analyzed in two ways: (1) to characterize the change in the definition using the distribution of outcome attributes by source category; and (2) to characterize the selectivity of the respondents for outcome attributes in each source category. The distribution of outcome attributes added by the CHE respondents, by source category, was reported (1) as a percentage of all outcome attributes added by the respondents, and (2) as a percentage of all outcome attributes available in each source category.

<u>Faculty self-reporting on the effect of the protocol.</u> Response frequencies for Questionnaire 2, items 8a and 8b, were counted for the "yes" and "no" responses, and were reported as percentage of the CHE faculty responses.