State of Qualitative Research in Engineering Education: Meta-Analysis of JEE Articles, 2005-2006

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ABSTRACT

With recent calls for expanding the scope and rigor of engineering education research, use of qualitative methods to answer research questions that can not be answered through quantitative methods is taking on increasing significance. Well-designed qualitative studies often build on epistemological consistency across theoretical perspectives, research questions, and research methods. We examine recent articles published in the *Journal of Engineering Education* to determine the overall prevalence of qualitative articles and the extent to which they appear epistemologically and methodologically consistent with the goals of qualitative inquiry. We find that there are very few qualitative articles published, and even fewer which show epistemological consistency across different aspects of the research design. These issues may limit the rich, descriptive information that could be gained from qualitative inquiry, limiting the contributions qualitative studies could make to engineering education. We call on researchers to expand their use of qualitative methods and to design their studies with careful attention to epistemological consistency across the design.

Keywords: epistemology, qualitative research, theoretical perspective

I. INTRODUCTION

Within engineering education as well as the wider educational community, there has been a recent call for improving the rigor of research being conducted (Albert et al., 2007; Bordage, 2001; Dirkx and Barnes, 2006; Lingard, 2007; Marchel, in press). Evaluating the rigor of research is never an easy task, but it becomes more complicated when the field, researchers, reviewers, and editors need to assess the value and rigor of emerging and less common research approaches within a particular field or discipline. In the pages of the *Journal of Engineering Education* (JEE) there has been a renewed emphasis on the quality of the research articles published, with development of a new mission, vision, and review criteria (Lohmann, 2005). The journal's strategic plan for 2005-2010 calls for JEE to

"be a world-class journal globally advancing rigorous scholarship in engineering education," and to "catalyze the formation of a vibrant community of scholars and practitioners dedicated to advancing engineering education through education research" (Lohmann, 2005). Other initiatives that have focused on improving the rigor of research in the field of engineering education include the ASEE Year of Dialogue, initiated in 2006, and the establishment of several workshops, such as the NSF-sponsored workshop on Rigorous Research in Engineering Education (Streveler and Smith, 2006).

Against this backdrop, there have been various studies identifying the components of rigorous education research. For example, the National Research Council study *Scientific Research in Education* (2002) outlines six scientific principles (e.g., pose significant questions that can be answered empirically, link research to relevant theory) that make up rigorous education research and Felder et al. (2005) provide an additional list of principles within the context of engineering education. A special issue of JEE in January 2005 outlines the broad array of research methods and issues of relevance to engineering education research. In that issue, Olds et al. (2005) and Turns et al. (2005) describe research designs, the research questions being asked, and the opportunities for future research across the broad scope of engineering education research. Olds et al. (2005) categorize the types of studies that can be conducted as "descriptive" and "experimental". In their framework, descriptive designs lead to improved understanding of the people affected by engineering education, while experimental designs aim to determine the effect of a particular intervention. Turns et al. (2005) conducted a meta-analysis of purposively selected publications and characterized them in terms of the population studied, the aspect of knowing what is probed, and the research approach. They suggest that one set of future opportunities lies in repeating these studies in different contexts (e.g., repeating studies done with freshmen on other populations, such as sophomores or graduate students).

The use of qualitative research methods in engineering education has certainly been recognized, and qualitative research is penetrating various areas of study due to its capability to offer alternative ways of knowing and viewing the empirical world. Qualitative research designs have the capability to capture the complexity of human behaviors in ways that are not possible when studies are based on prediction and randomized controls. In the context of engineering education, Olds et al. (2005) include qualitative methods along with surveys in their discussion of "Descriptive Designs", and emphasize that the research questions should drive the type of investigation (e.g., quantitative or qualitative). In their meta-analysis, Turns et al. (2005) compiled examples from both quantitative and qualitative studies, with an aim of providing an overview of the variety of studies being conducted within the context of engineering education.

Although careful examination of how research purposes and study designs are theoretically driven has not been conducted for engineering education, it has been done in other professional fields, such as medical education, adult and continuing education, and psychology. For example, in medical education, examination of comments made by peer reviewers of manuscripts found that lack of a theoretical or conceptual framework in the problem statement was cited in 19 percent of the negative comments made, and lack of a theoretical framework in interpretation of results was cited in 5 percent of the negative comments (Bordage, 2001). In another study, interviews with "influential figures" in medical education revealed that lack of familiarity with theoretical frameworks and lack of training in social science methods were two factors seen as influencing the quality of medical education research (Albert et al., 2007). In a reflective article on eight years of qualitative research in medical education, Lingard (2007) argued that research questions and the context of research are influenced by selected theoretical tools, and that the dominant quantitative paradigm in the field of medical education has influenced her research questions. In a study of qualitative articles published in the field of adult and continuing education, Dirkx and Barnes (2006) find a tendency towards implicit use of a post-positivist[1] perspective, primarily evidenced by the use of *a priori* categories to code the data. Marchel and Owens (2007) analyzed the abstracts of articles appearing in all 57 journals published by the American Psychological Association or its divisions. Qualitative articles were less than 5 percent of all articles published in all but three of these journals. Thus, it appears that across several professional fields qualitative articles are published in limited frequency, and many of the published articles do not meet the standards expected of rigorous scholarly work (including both quantitative and qualitative inquiries).

Even though there have been no studies that have examined the nature of the research and research designs as reported in engineering education publications, there have been other examinations of articles published in JEE such as the content analysis of the articles (Wankat, 1999 and 2004; Whitin and Sheppard, 2004). In response to increasing interest for qualitative studies, and for the possible contributions of qualitative inquiry to the field of engineering education, we see it as important to facilitate conversations about the state of qualitative research, the rigor of qualitative research conducted and to be conducted, and how some common epistemological and theoretical assumptions shape rigorous qualitative research projects. We also recognize that the epistemological and theoretical stances commonly associated with qualitative research may not be familiar to engineering education researchers, who have been typically trained within the post-positivist and quantitative perspectives. Thus, in order to increase researchers' understandings of qualitative research practice, it is essential to examine the types of qualitative studies conducted within engineering education and to carefully reflect on the research questions, theoretical perspectives, and data collection and analysis methods that are either explicitly stated or implicitly implied by these studies.

With this study, we respond to this methodological need and hope to advance the field's understanding of qualitative research practice. The specific purpose of this study is to examine qualitative articles published within the *Journal of Engineering Education*, in order to identify the research questions, theoretical perspectives, and methods used by the authors, and to compare those to the perspectives typically understood to describe qualitative research. More specifically we ask: What research questions, theoretical perspectives, and methods are used by engineering education researchers who make reference to qualitative research in their work? And how are the authors' theoretical and methodological choices made explicit in these research articles? We would like to emphasize that our intention is not to criticize positivist and post-positivist research, or to imply that qualitative research can only be conducted within an interpretivist perspective, nor is it our intention to provide a ranking of the quality of the articles examined. Rather, it is our intention to evaluate and reflect on one aspect of rigor, namely the consistency between authors' theoretical perspectives and research design, whatever paradigm or theoretical perspective the authors prescribe to and apply within their research projects. Even though theoretical and epistemological consistency contributes to the validity and trustworthiness of one's research, validity in qualitative research is not the focus of this paper. For both classical and more recent discussions on validity in qualitative research, the readers can refer to a number of authors (Angen, 2000; Denzin and Lincoln, 2000; Devers, 1999; Hesse-Biber and Leavy, 2004; Lather, 1993; LeCompte et al., 1992; Lincoln and Guba, 1985; Schwandt, 2001) and for a specific discussion in the context of qualitative engineering education research see Leydens et al. (2004).

II. DESCRIPTIONS OF QUALITATIVE RESEARCH

Qualitative research cannot be defined; it can be only described since the qualitative research community presents a large spectrum of different theoretical perspectives, methodologies, and methods. In addition, the qualitative research tradition has been in constant flux, responding to changing cultural and historical movements (see Denzin and Lincoln (2005) for a discussion on movements in qualitative research). For example, positivist oriented qualitative research approaches were common and popular in the late 80's through the 90's, when qualitative evaluation research gained more popularity (Miles and Huberman, 1994; Patton, 2001). However, recently many qualitative researchers have attempted to distinguish themselves from quantitative researchers by emphasizing different ways of knowing available through qualitative research approaches and using theoretical perspectives beyond post-positivism. In engineering education research as well, it has been recognized that qualitative research can, and should, move beyond positivism or post-positivism and examine the field from other perspectives (Borrego, 2007; Leydens et al., 2004).

Denzin and Lincoln describe qualitative research as "a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible" (Denzin and Lincoln, 2005, p. 3). In other words, in qualitative research the context, or setting, of the phenomenon being investigated takes on great importance. Similarly, Hatch (2002) proposes that natural settings, participant perspectives, extended firsthand engagement, focus on meaning, wholeness and complexity, emergent and evolving research design, inductive data analysis, and incorporated researchers' reflectivity are characteristics of qualitative research. At the same time, qualitative research is seen as being highly flexible in the theoretical

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[1]For definitions of qualitative research terms used in this article, see the Appendix.

perspectives and methodologies that are used. Freeman et al. (2007, p. 25) point out that "qualitative research is open and supple, and one of its strengths is that it incorporates philosophies, theories, and research designs and methods as diverse as post-positivist multimethods approaches and postmodernist social critiques".

Finally, Crotty (2003) emphasizes the role of epistemology and various levels of theory in the qualitative research process. He proposes that the entire qualitative research process is influenced by epistemology and theoretical perspective, which in turn shape the questions researchers are able to ask about the world and what kinds of methods are suitable to address particular research questions. Qualitative research approaches enable researchers to investigate individuals' behaviors, associated cultural phenomena, and socio-political influences and processes, in-depth and from the perspectives of the study participants. It allows participants to define factors and highlight influences that they find meaningful and essential to describe their life experiences. Additionally, qualitative investigations are often carried out in natural settings and specific attention is paid to process rather than outcomes or products (Bogdan and Biklen, 2006). It could be argued that qualitative inquiry generates theories that are context-specific and participant-driven, which later can be generalized to other contexts.

A. Theoretical Perspectives in Education Research

According to Luttrell (2005), qualitative research is learned through practice and a continuous dialogue with theory. As a result, methods, analytical approaches, and other techniques do not exist in a vacuum; rather, they are theoretically grounded and applied within particular theoretical frameworks with different results. Next, we will discuss a few examples of different theoretical perspectives that a qualitative researcher can bring to a study. (For a more detailed description that includes perspectives that fall under the broad category of interpretivist, as well as others such as critical theory, postmodernism, and poststructuralism, see the book by Crotty (2003)). Table 1 compares general characteristics of various theoretical perspectives (McMillan and Schumacher, 2001; Waller, 2005). We would like to note that the following examples and categorizations should be used as a guidance, not as a truth or the only way to conceptualize theories, applications of methods, or epistemological consistency.

All of the theoretical perspectives in Table 1 have specific traditions, histories, and practices that might vary considerably within each perspective. Due to space limitations, we will not discuss all of these perspectives in detail. Rather, we will illustrate how positivism or post-positivism differ from all other more situational and contextual theoretical perspectives. We will refer to "situational perspectives" as a way to describe interpretive, critical, and poststructural perspectives with one term.

The goal of post-positivist research (quantitative or qualitative) is generally to test hypotheses and to determine cause-and-effect relationships between variables (Creswell, 2007). Thus, the variables to be tested are often deterministic, driven by previous research and identified in advance. Effective experimental research in the post-positivist perspective prefers random assignment of participants to control and treatment groups in order to ensure the results are not biased by differences among the participants. In addition, concerns over sample size and participant characteristics are paramount in order to identify the presence or absence of significant differences between the two groups and to allow generalizability (discussed later).

In contrast, the purpose of situational theoretical perspectives (such as interpretivism, critical/emancipatory, and postmodern/poststructural perspectives) is to provide descriptions or critiques of particular situations in order to understand, criticize, emancipate, or deconstruct specific phenomena. Situational perspectives are generally inductive in contrast with the deductive approach of post-positivist work. Thus, post-positivist research does not allow for insights and findings to emerge throughout the data collection and analysis process, while the emergence of insights

Theoretical perspective	Post-positivist	Interpretivist (constructivism, social constructionism, hermeneutics, phenomenology)	Critical/emancipatory	Postmodern/poststructural
View on reality	Single falsifiable reality	Multiple subjective realities	Multiple subjective and political realities	Multiple fragmented realities
Purpose	To find relationships among variables, to define cause and effect	To describe a situation, experience, or phenomenon	To produce a socio-political critique	To deconstruct existing 'grand narratives'
Methods	Methods and variables defined in advance, hypothesis driven	Methods and approaches emerge and are to be adjusted during study	Methods and approaches designed to capture inequities	Methods and approaches generated during the study
The role of researcher	Researcher is detached	Researcher and participants are partners	Researcher and participants are activists	Researchers and participants have various changing roles
Outcome or research product	Context-free generalizations	Situated descriptions	Critical essays, policy changes	Reconceptualized descriptions of the phenomenon

Table 1. Comparison between theoretical perspectives.

throughout data collection and analysis is one of the strengths of research based on the inductive approach of situational perspectives. Participant selection also differentiates post-positivist research from its situational and contextual counterparts. In situational theoretical perspectives, fewer participants are generally studied in order to investigate the experiences of those particular participants in great depth. In addition, participant selection is generally purposeful. Rather than random or convenience sampling, particular participants are selected because their unique experiences or individual situations provide important insights. In some studies the outlier case is one of particular interest, as the contrast with the typical case can help to conceptualize and understand specific situations.

Two additional differences between post-positivist and situational perspectives deserve to be discussed. The first is the role of the researcher. In the post-positivist perspective, the researcher strives to be detached, so as to remain objective and not influence the results of the experiment. In contrast, researchers utilizing situational perspectives recognize, value, and often celebrate the role of the researcher in the research process. The researcher brings his or her subjectivities, roles, assumptions, and theories to the work, which influence all aspects of the research, particularly the analysis and interpretation of the data. These subjectivities are explicitly recognized and stated in order to understand how researchers' experiences and roles shape the data analysis process and interpretation of data. Thus, recognizing the role of these subjectivities contributes to enhancing the validity of the research. Similar subjectivities need to be recognized within quantitative research. However, in quantitative research those perspectives brought into the research by the researcher influence the choice of hypotheses and variables to be studied. In other words, in quantitative research the researcher perspective tends to influence the planning of the research, while in qualitative research the influence is more on the data analysis and interpretation (although it still influences the planning). In both cases, recognizing these perspectives reduces potential bias and enhances validity.

The other important difference is the generalizability of the research. Freeman et al. (2007) have summarized the differences between the two. Post-positivist research strives for what has been called nomological generalizability: the results apply anywhere, anytime, to anyone, in any setting. While this is not always practical, this goal lies at the heart of many of the requirements of post-positivist research (adequate sample size, random assignment, etc.). In contrast, situational research strives for representational generalizability, or for generalizability within a case. In other words, the experiences of the various participants are generalized, but only within the context of that particular research setting. Further generalization to other settings occurs as additional studies are done in other settings and the results are compared across settings, or when readers make their own generalizations based on their empirical knowledge.

B. Qualitative Research Questions

The careful planning and sophisticated design of research questions serve as a strong backbone for research proposals and projects. According to Kuhn (1996), research questions exemplify conceptual, theoretical, and methodological connections. Research questions are limited by their possible solutions; thus, answers to the questions should be consistent with the epistemological and theoretical assumptions used in that particular study. For example, if researchers aim to explore participants' perspectives, they ought to analyze and report participants' perspectives, not the perspectives of the researchers or the outcomes of their hypotheses. Additionally, research questions indicate commitment to the particular research instrument or methods. In other words, research questions ought to be specific enough to indicate the theoretical orientation and methodological approaches used in the study. Furthermore, research questions provide a bridge between the theoretical and empirical worlds. According to Denzin and Lincoln (2005), a qualitative study commences when a researcher moves from research questions to theoretical perspectives and finally to the empirical world. "The questions represent the facets of an empirical domain that the researcher most wants to explore" (Miles and Huberman, 1994, p. 23). Morse and Richards (2002) propose that qualitative research questions study meanings, processes, and experience, among others. Thus, qualitative research questions often ask "why" and "how" rather than "how many." Hatch (1995), in turn, suggests that although the discourse in which qualitative research questions are framed may vary, they will not assess factors, variables, causes or determinants.

C. Data Collection and Analysis Methods in Qualitative Research

At one level in qualitative research, the data that are collected are words, texts, visual materials or other types of non-numerical data. Some examples of qualitative research designs and methodologies include case studies, life histories, genealogies, interview studies, and forms of collaborative research. "Justification of our choice and particular use of methodology and methods is something that reaches into the assumptions about reality that we bring to our work. To ask about these assumptions is to ask about our theoretical perspective," Crotty explains (2003, p. 2). Various justifications for method choices, and the differences in data collection and analysis methods, indicate a researcher's epistemological interests and commitments. In Table 2 we illustrate how specific data collection methods could be viewed more suitable for some theoretical perspectives than for others due to the epistemological possibilities associated with a particular method. In other words, the main purposes why specific data collection methods are used indicate specific epistemological interests that need to be matched with appropriate theoretical perspectives. While combinations of perspectives and methods other than those given in Table 2 are possible, the table presents some of the most common ways in which methods are matched with theoretical perspectives. Greckhamer and Koro-Ljungberg (2005) argue that the processes of data collection and analysis are interrelated, serving epistemological goals of particular knowledge production. "Researchers can neither collect data without keeping in mind their epistemological purpose nor can they use particular analysis methods without considering their appropriateness to produce the type of knowledge desired" (Greckhamer and Koro-Ljungberg, 2005, p. 733). Furthermore, the implications of how the researcher's theoretical perspective affects his or her interpretation of the data has been explored by Yanchar and Williams (2006). In addition, Yanchar and Williams point out that particular methods are outgrowths of particular theories of how to study phenomena. Thus, choice of a method inevitably tends towards one or another theoretical perspective, regardless of whether or not this is explicitly stated (or even recognized) by the researcher. As stated by Yanchar and Williams (2006, p. 4), " . . . it is important to recognize that the adoption of a method will implicitly commit researchers

	Observations	Individual interviews	Focus group interviews	Document/archival research	Survey and questionnaire	Visual materials/video
Main Purposes	To witness and collect data in actual empirical/real life settings *Often used as secondary data*	To gain individual participant's perspective *Primary data*	To create socially constructed knowledge and to gain a group perspective *Primary data*	To gain historical perspective *Primary/secondary data*	To collect data from large samples *Primary data*	To gain holistic and culturally situated perspectives *Secondary data*
Suitable theoretical perspectives	Post-positivism, interpretivism (if data are used to facilitate individual and/or collective meaning making)	All except post-positivism	All except post-positivism (most suitable for social constructionism)	All perspectives	Post-positivism	All perspectives
Suitable data analysis methods	Content analysis, domain analysis etc.	Grounded theory, phenomeno-logical analysis, discourse analysis, conversation analysis etc.	Grounded theory, discourse analysis, conversation analysis etc.	Content analysis, archealogy, genealogy, discourse analysis etc.	Content analysis	Visual analysis methods, semiotics etc.
Whose perspective is highlighted?	Researcher's	Participant's	Participant's	Mostly researcher's if she/he is doing all interpretation	Participant's and researcher's (development of questions)	Mostly researcher's if she/he is doing all interpretation

Table 2. Data collection methods in qualitative research.

who use it to certain kinds of assumption-based outcomes that both reveal and conceal (or obscure) phenomena in particular ways and that bring with them certain affordances and limitations".

The connection between theoretical perspectives and methods is not simply an academic or conceptual argument, but has a clear impact on future research practice and the findings that result from any particular research study. For example, Yanchar and Williams critically analyze a mixed method study on cooperative learning, in which both significance testing of quantitative data and a phenomenological analysis of qualitative data were used (Onwuegbuzie and DaRos-Voseles, 2001). As analyzed by Yanchar and Williams, the theoretical perspective inherent in this study is driven by the quantitative data, reflecting a post-positivist view. Although qualitative data is collected, it does not provide a rich, contextual description of the phenomenon of cooperative learning. Rather, it serves to support the quantitative results by providing limited descriptions of what the students liked and disliked about the cooperative learning experience. This perspective drives the original authors' recommendations for future work, in which they advocate additional post-positivist practices (such as adding a control group, larger samples, etc.). This type of approach is certainly useful, as it provides an understanding of the relationships between cooperative learning practices and student outcomes. However, as Yanchar and Williams point out, if the research were being driven by an interpretivist perspective, the recommendations would likely have focused on more detailed, in-depth, open-ended investigations of fewer participants in order to obtain detailed descriptions of their experiences.

Along these lines, we argue that in order to utilize the rich, contextual information available in qualitative research, researchers must be aware of the theoretical perspective they bring to the research and understand how it informs the design and the results of their research.

III. METHODS FOR META-ANALYSIS

The articles selected for the meta-analysis described in this article were published in volumes 94 and 95 (2005 and 2006) of the *Journal of Engineering Education*. These particular volumes were chosen because they reflect the change in the journal's mission and review criteria that were initiated in 2003[2]. The articles examined include both full articles and Research Briefs, but do not include articles from The Academic Bookshelf or editorials. Also excluded is issue 1 of 2005, a special issue that included state of the field types of articles. All 48 articles that appeared over the two year span were read in their entirety, and a set of information that characterized the research design, methods, and analysis were identified including: (1) keywords in the title that would suggest whether it was a quantitative or qualitative article, (2) the purpose statement, (3) research questions, (4) type of data collected (quantitative, qualitative, or

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[2]The journal published refined review criteria in January 2008 which encourage both quantitative and qualitative research manuscripts.

mixed), (5) data collection methods, and (6) data analysis methods. Those articles identified by us as either qualitative or mixed method were then further analyzed to distinguish the following additional characteristics: use of literature references for the methods that were used and the theoretical perspective (either explicitly stated or implied). Out of the original 48 articles, nine of them were identified as qualitative and six of them as mixed method. It is important to note that our definition of qualitative was fairly liberal. For example, an article was considered qualitative if the data was textual or descriptive, regardless of the analysis methods used. Of the remaining articles, three were not empirical research articles, falling in the categories of literature reviews or theoretical articles, and 30 were quantitative.

One of the limitations of this study is that we are analyzing research reports, not the actual conduct of the research itself. We recognize that there are many factors that can contribute to how a research report is written. For example, interpretivist research may be written in a way to be more acceptable to a primarily post-postivist audience, or there may be assumptions on the part of the researchers as to what constitutes "acceptable" research published in a particular journal. Nevertheless, the research report must accurately reflect the research practice, so that the findings can be properly understood in the context that the researchers intended when the study was designed and carried out.

IV. META-ANALYSIS OF JOURNAL ARTICLES

Table 3 illustrates the information that was collected for all 48 articles, using the articles in volume 94, issue 4 as an example. A total of 26 out of all 48 articles had keywords in the title which indicated either a quantitative or qualitative research approach. For example, "emergent," "experience," and "discourse" were used as possible key words for qualitative articles, and "indicators," "factors," and "comparison" for mixed method or quantitative articles. In fact, for all the articles with keywords except one, identification of whether it was quantitative or qualitative was successfully made from the title alone before the article was read. The exception was an article by Roselli and Brophy (2006), in which the word "experiences" was used in the title of a quantitative article.

Additional information on the research design for each article was obtained by examining the purpose statement and research questions. The purpose of each article was generally identifiable, although not all articles had an explicit purpose statement. However, only 19 of the 48 articles contained either research questions or a set of hypotheses.

Following the initial analysis of all articles, the qualitative and mixed methods articles were examined more closely. The qualitative articles were divided into three groups that represented the degree of alignment with general theoretical assumptions embedded in qualitative inquiry. Group I articles were those which met various characteristics for well-articulated and epistemologically consistent qualitative articles and research designs (e.g., situational and contextual purpose statement, research questions that investigate a phenomenon in depth, essential role of the researcher, methods that facilitate and promote situated knowledge, and a clearly defined theoretical perspective which informed the research design). Additionally, Group I articles resembled current literature on qualitative research methods and design. Group II articles were those which

exemplified many characteristics of qualitative research but which lacked a degree of epistemological consistency. In addition, the methods used in Group II articles did not completely support the types of research questions asked (e.g., research questions focused on participants' experiences, but observation, for which the focus is on the reseacher's interpretation of the empirical world, was used to collect data). Group III articles were those which were based on qualitative data (e.g., interviews or visual materials), but for which the analysis and interpretation were clearly not qualitative in nature. Tables 4-6 present the collected data for each of these groups, while Table 7 presents the data for the mixed methods studies.

Group I articles all used well-established qualitative data collection and analysis techniques. The selection of data collection and/or analysis methods was also grounded in qualitative methodology literature as exemplified through the use of methodology literature references for three of the four Group I articles. The data analysis methods included observations, semi-structured individual interviews, and focus groups, all of which allowed for collection of in-depth, rich, descriptive data. The analysis methods represented well-established and rather sophisticated methods recognized within the qualitative research community, including discourse analysis, thematic analysis, and Spradley's domain analysis. Group I articles also all had well-defined theoretical perspectives, even though they were often not stated explicitly or cited appropriately. Nevertheless, all of these articles contained clear statements that allowed readers to identify the theoretical perspective taken by the authors. For example, "The use of small numbers of participants . . . facilitates deep exploration of experiences, perceptions, and beliefs that in turn leads to rich and authentic description" (Friesen et al., 2005) (constructivist or phenomenological perspective) or "It is with the goal of supporting the voices of women undergraduate engineering students that this research was undertaken . . ." (McLoughlin, 2005) (feminist perspective). Additionally, Group I examples utilized rather small samples, which enabled researchers to conduct inductive and more in-depth analysis.

However, there were various aspects of the Group I articles that could have been revised in order to improve the transparency between theory and method. For example, McLoughlin et al. (2005) did not specify how observations were used or analyzed, and how observational data complemented or contradicted interview data. Additionally, Tonso (2006) did not clearly state why the simultaneous use of domain analysis, constant comparative approach, and thematic analysis was needed and how the data analyzed through the combination of these methods supported gendered and feminist ways of knowing. Donath et al's (2005) use of discourse analysis within the framework of social constructionism was exemplary, providing a consistent link between the analysis of the interactions occurring in a group and how socially constructed knowledge could be analyzed within the group. In contrast, Friesen et al. (2005) used the constant comparative method in a study whose implicit framework was phenomenology. The epistemological inconsistency between methods and assumed theoretical perspective became evident in the ways in which phenomenology seeks to obtain a detailed description of the essence of a phenomenon at the individual and collective level, but not to systematically compare across the cases or individuals. The comparisons between various groups are the main focus, for example, of the constant comparative method. It could also be argued that the lack of research questions for this study may have contributed to this inconsistency.

Authors	Title*	Purpose	Research Questions	Data	Data Collection	Data Analysis
(Shiavi and Brodersen, 2005)	Study of instructional modes for introductory computing	To illustrate the best mode of instruction	none	quantitative	Survey with Likert-type response, MBTI	Contingency table comparing distributions with chi-square
(Steif and Dantzler, 2005)	A statics concept inventory: Development and **psychometric analysis**	To understand through multiple choice questions	none	quantitative	Multiple choice concept test	Item analysis, Cronbach's alpha, correlations, t-test
(McLoughlin, 2005)	Spotlighting: **Emergent gender bias** in undergraduate engineering education	To introduce a conceptual framework and suggest changes	none	qualitative	Longitudinal interviews	Excerpts from interviews placed into (pre-determined?) categories; specific phenomenon emerged from analysis
(Loui, 2005)	**Ethics** and the **development of professional identities** of engineering students	To identify potential for deep learning	How do undergrads develop identities? How can instruction affect development?	qualitative	Student essays – written specifically to answer research questions.	Words from essays coded into (predetermined?) categories.
(Hirsch et al., 2005)	Enhancing core competency learning in an integrated summer research experience for bioengineers	To study the impact of instructional interventions	Can students make progress in understanding using informal learning? What do they learn?	qualitative	Student-created concept maps.	Maps analyzed for number of nodes and presence of pre-determined elements. Statistical analysis using McNemar's test.
(Donath et al., 2005)	Characterizing **discourse** among undergraduate researchers in an inquiry-based community of practice	To describe, illustrate, and analyze discourse in an active learning environment	What linguistic events occur? How do the events pattern?	qualitative	Primarily videotape of a single learning session; supplemented with observations over a 3 year period.	Codes initially developed by general observation of sessions. Videotaped session was then coded, with codes refined during coding.
(French et al., 2005)	An **examination of indicators of** students' success and persistence	To investigate the ability of variables to predict students' success and persistence.	none	quantitative	Demographic data, two quantitative instruments.	Correlations, regression.

*Words in bold are keywords that identify the article as quantitative or qualitative.

Table 3. Example from volume 94 issue number 4 of initial analysis of all articles.

Examination of Table 5 indicates some general limitations shared among the Group II articles. In these articles, the literature basis or theoretical and epistemological groundings were not systematically and logically guiding the data collection or qualitative data analysis. In some cases the analysis procedures did not appear to follow the in-depth or inductive approaches of qualitative

Reference	Research Questions?	Data Collection	Data Analysis	Method References	Theoretical Perspective
(Donath et al., 2005)	Yes	Videotape of group session.	Discourse analysis.	Extensive	Social constructionism
(Friesen et al., 2005)	No	Semi-structured individual interviews and focus groups.	Constant comparative method.	Extensive	Phenomenology
(McLoughlin, 2005)	No	Longitudinal semi-structured interviews.	Categorization of interview excerpts, writing of descriptive paragraphs	None	Phenomenology, feminist/action research
(Tonso, 2006)	No	Participant observations, student survey	Spradley's domain analysis and constant comparative approach, thematic analysis	Key texts in the area	Gender studies.

Table 4. Summary of Group I qualitative articles.

Reference	Research Questions?	Data Collection	Data Analysis	Method References	Theoretical Perspective
(Loui, 2005)	Yes	Written essays	Simple coding	None	Post-positivist
(Wankat, 2005)	Yes*	Open ended surveys	Responses compiled into summaries	Limited	Post-positivist
(Jonassen et al., 2006)	No	Structured interviews	Item counts, grounded theory	Limited	Constructivist/ phenomenology

*Presented as hypotheses rather than research questions.

Table 5. Summary of Group II qualitative articles.

research, relying on simple categorization and deductive coding. Sample sizes were too large for in-depth or inductive analysis. The theoretical perspectives of these articles were also not as clear as in Group I, and it was necessary for us to infer the perspective from various statements in the articles that made references to the authors' preferred ways of knowing. We also found that these articles used quantitative terminology to refer to the qualitative research process. For example, in the Wankat (1997) article, the emphasis was on testing a set of hypotheses, while Jonassen et al. (2006) described the case library building process as "the query vector is matched against all case vectors in the high dimensional vector space." Not only was the vocabulary drawn from quantitative discourses in some of the Group II examples, but also the underlying assumptions were based on quantitative inquiry. For instance Loui (2005) states, "The findings presented below may not generalize to other situations . . ." which suggests he sees the situatedness and context specificity as limitations of the study.

We would like to emphasize that these articles were not placed into Group II because of their post-positivist perspectives. However, the use of a post-positivist perspective in conjunction with situated data collection and analysis methods might indicate that the researchers are either not familiar with, or are uncomfortable with, situational perspectives, and have not carefully considered the need to maintain consistency among research questions, theoretical perspective, and methodology. Our interpretation of these articles is similar to what was found by Borrego for participants in an engineering education workshop (2007). She found that engineering faculty began the workshop not understanding the value of explicitly identifying a theoretical framework, because the theoretical frameworks of disciplinary engineering research are well-established and do not need to be explicitly identified. For our study, the use of post-positivist perspectives and quantitative language in the Group II articles may similarly indicate that these researchers are still operating in a manner driven by their disciplinary research approaches. Despite these limitations, Group II articles demonstrated the value of participants' open-ended responses and the importance of individuals' perspectives. It could also be argued that the overall use of qualitative data by these authors reflect a positive trend towards in-depth and more complex understandings of phenomena of learning and teaching in engineering education.

The Group III articles listed in Table 6 provided two interesting cases for how qualitative data can be used for various purposes, including prediction and generalization. These articles were placed in Group III because they both involved collection of qualitative and open-ended information in contrast to structured and predetermined data. However, in Group III articles qualitative data were analyzed using quantitative means or analysis methods directly borrowed from quantitative research. Group III articles still provided useful and interesting examples of the ways in which the research design was approached utilizing data and materials that

promoted in-depth investigations and knowing. In the article by Hirsch, et al. (2005), students were asked to create concept maps on a particular engineering topic. These concept maps, that could have provided rich information using techniques such as visual analysis, were instead quantified by the number of nodes and connections. In addition, in their design a concept map created by an expert was taken as one version of a "correct" map, and the students' maps were quantified by how many of the concepts they had in common with the expert. The quantitative results were compared to significance testing. From the purpose statement and research questions, it appears that the authors' purpose was to conduct a quantitative study, in which students' understanding of a

Reference	Research Questions?	Data Collection	Qualitative Data Analysis	Method References	Theoretical Perspective
(Hirsch et al., 2005)	Yes	Concept maps generated by students	Structure of concept maps quantified, compared by significance testing. Map created by expert considered to be "correct"	Several references on analysis of concept maps	Post-positivist
(Hutchison et al., 2006)	Yes	Online survey to 1387 students, included Likert-type items and open question to list and rank factors	Likert items not discussed. Ranked items categorized, summarized with statistics, compared with significance testing	Limited	Stated as phenomenography, exemplify a positivist perspective

Table 6. Summary of Group III qualitative articles.

Reference	Research Questions?	Data Collection	Qualitative Data Analysis	Method References	Theoretical Perspective
(Thompson et al., 2005)	None	Likert-type survey and participant written reflections	Identifying general patterns	Limited	Intervention based on social constructivism; perspective for the research design could not be identified
(Bilen et al., 2005)	Yes	Surveys, content knowledge test, focus groups	Grounded theory	Key texts	Post-positivist
(Rutar and Mason, 2005)	No	Likert-type survey, grades, interviews (interview protocol not described)	Divided into categories and summarized	None	Post-positivist
(Dabbagh and Menasce, 2006)	Yes	Survey with Likert-type items, yes/no items, and short answer items	Summary of answers given, grouped by question	None	Post-positivist
(Grimes et al., 2006)	Yes	Observations, interviews, survey, student work	None	None	Post-positivist
(Fincher and Tenenberg, 2006)	No	Publication count of workshop participants, open-ended survey	Categorization of responses	Limited	Could not be identified

Table 7. Summary of mixed method articles.

certain topical area was accessed through an initially qualitative data source (concept maps), which is one potential use of concept maps for assessment purposes. Overall, this paper utilizes a post-positivist perspective, which is epistemologically consistent across research questions, methods, and data analysis.

In contrast, the theoretical perspective as identified in the paper by Hutchison, et al. (2006) was not in unison and consistent with the study design. The authors state that they were using a phenomenographical approach, which results in "a description of the so-called 'lived experience' of people, their perceptions of what it means to go through an experience or phenomenon." However, the data collection and analysis procedures did not allow for the detailed description of the phenomenon, or textural and structural descriptions of individuals' experiences called for by this theoretical perspective. The data collection involved an online survey of over 1,100 students, which is far too many to obtain detailed descriptions of individuals' experiences. In fact, the analysis consisted of frequency counts of student responses. A more appropriate method to obtain the level of description called for by phenomenography would be interviews (semi-structured or unstructured). Moreover, the terminology used and the purpose of the paper appeared to be removed from the goals and purposes of qualitative inquiry. For example, the authors referred multiple times to "a difference...that is statistically significant", which also fit well with the authors' research questions of "Which aspects of students' first engineering course influence their self-efficacy beliefs, and how do those aspects vary by gender?" Hutchison, et al., also recognized the limitations of their approach at obtaining a deep understanding, stating that, "In order to gain a better understanding of these and other factors that have been identified as sources of students' efficacy beliefs, interviews facilitated by survey data have been conducted. Analysis of these interviews... will lead into improved insight into how efficacy beliefs are formed." This article illustrates how the term "qualitative" can be cited and associated with research that is actually quantitative in its terminology and approaches.

Finally, the articles that we categorized as mixed methods studies were sometimes difficult to characterize in terms of the key aspects of the research design. Studies in this category commonly assessed a particular course or workshop. The use of mixed methods designs in these cases likely reflected the "pragmatic" approach to program evaluation taken by mixed method researchers with the goal of determining if a particular approach to teaching or a particular workshop was successful. The researchers identified certain measures that were meaningful to that situation and used them in assessing effectiveness. The sophistication of the data analysis varied widely, ranging from simple categorization of responses to grounded theory. For the most part, these studies were post-positivist in nature, with the quantitative data being analyzed through significance testing and the qualitative data being used in a subordinate role to support the quantitative results: " ...a comprehensive description and content analysis of the data collected from the short answer questionnaire for all students...was performed to triangulate the results of the independent t-test" (Dabbagh and Menasce, 2006), and "The results of the qualitative data were directly compared with the results of the quantitative data to see if the statistical trends could be supported by the emergent qualitative themes" (Bilen et al., 2005). However, the pragmatic approach taken by the researchers made it difficult in some articles to identify the theoretical perspective. The articles seemed to focus on the individual

course or workshop, and we might describe these studies as 'mechanical', lacking the attempt to generalize from a post-positivist perspective, but also not providing the deep understanding of an interpretivist and situational perspective.

VI. CONCLUSIONS

Our analysis shows the theoretical and methodological diversity of papers that are currently being published within JEE. Studies span the range from quantitative to mixed methods to qualitative, and cover theoretical perspectives from post-positivist to various situational perspectives. It is important to highlight that all of these papers have their own strengths, and make important contributions to the development of our overall understanding of issues within engineering education. We believe that it is this growing diversity of approaches and perspectives that marks the field of engineering education as vibrant and strong. The use of qualitative methods in these articles provides important insights that would not have been possible through quantitative approaches. For example, the approach taken by McLoughlin (2005) allowed a new phenomenon, spotlighting, to emerge from the analysis. This unexpected phenomenon could not have been identified by quantitative methods, in which the specific phenomenon of interest must be identified prior to data collection in order to create appropriate measurement instruments. Similarly, Donath's et al. (2005) use of qualitative methods provides insight into the ways that student teams work that would not have been possible with quantitative methods.

However, in order to further strengthen the field methodologically, we call for more informed use of qualitative methods to answer important questions that can not be answered through quantitative methods. Over the two year period we examined, only nine qualitative articles were published. We argue that increasing use of qualitative methods will expand our understanding in areas such as the way students learn in different settings, how student teams interact, and how socio-political context shapes students' learning.

At the same time, we caution researchers intending to use qualitative methods to design their studies based on existing qualitative method literature that acknowledges the role of theories of knowing, and based on one's specific areas of epistemological interest. Additionally, we would like to remind readers that one of the dangers in conducting qualitative research is that it may appear easy and less rigorous than quantitative research. While quantitative research requires use of statistical methods which can provide an aura of trustworthiness, qualitative research can appear at first glance as if it simply involves interviewing a few people and then writing up a summary. As stated by Hoaglin et al. (1982, p. 134), "Most people feel they can prepare a case study, and nearly all of us believe we can understand one".

In fact, qualitative research can be just as difficult to conceptualize, and be as methodologically and theoretical challenging, if not more challenging, than quantitative research. It is important for qualitative researchers to strive for high standards of rigor, including theoretical consistency, transparency in methods, acknowledging researchers' involvement in and contributions to knowledge produced, citing of appropriate references for data collection and analysis methods, creating an audit trail to ensure the interpretation is consistent with the data, and appropriate use of the language and traditions of qualitative research, to mention a few.

We believe that increasing the use of qualitative methods in engineering education research will allow for new understandings to emerge. Continuous and systematic exposure to the methodological tools available to study complex problems and socio-cultural phenomena, through offering a variety of methodological and theoretical workshops and training courses suitable for qualitative researchers, would assist researchers interested in qualitative research questions and methods to conduct rigorous studies.

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APPENDIX

The following provides brief definitions of qualitative terminology used in this article. For more complete definitions, as well as definitions of additional terms, see the Dictionary of Qualitative Inquiry (Schwandt, 2001).

coding of data: The process of assigning summarizing terms, labels, or categories to segments of qualitative data.

critical/emancipatory perspectives: Theoretical perspectives that aim to challenge existing social practices and belief systems, and to inspire change. Quite often the focus of critical or empancipatory research is on disadvantaged groups, such as women or minorities.

deconstruction of data: The process of breaking down data (usually text) to reveal the latent meanings and presuppositions of that data in order to create new interpretations, to reveal and displace hidden and taken-for-granted assumptions.

deduction: When social science researchers refer to deduction, they are often referring to the hypothetico-deductive method. In this method, a model or theory is developed to explain human behavior, and that model or theory is tested through empirical observation. In other words, pre-existing theory drives data analysis.

emergent: Qualitative research requires as much planning as quantitative research. However, unlike quantitative research, data collection and analysis methods can evolve during the study. In data collection, the researcher may become aware of a participant or situation that provides new insight to the phenomenon of interest. In data analysis, the process of coding is often conducted in an emergent fashion, in which codes are allowed to develop and evolve out of the data as the analysis proceeds, rather than being defined in advance.

epistemology: Refers to different ways of knowing about the world. Three common epistemologies are objectivism (there is an inherent truth, which exists apart from any consciousness), constructionism (meaning is created by interaction between observer and the observed), and subjectivism (meaning is created by the observer and is imposed on the observed) (Crotty, 2003).

induction: The process of generating theories or explanations from data.

interpretivism: A theoretical perspective that believes that truth is situational, and so it depends on the context of the environment, the background and prejudices of the observed, as well as perspectives brought to the situation by the observer. Interpretivism is a large category that encompasses many theoretical perspectives such as hermeneutics and phenomenology.

method: The specific strategies and techniques used to collect and analyze data (e.g., interviews, survey, grounded theory, discourse analysis).

methodology: An overall research approach (e.g., case study, action research).

positivism and post-positivism: Theoretical perspectives that both state there is an empirical truth. The difference is that positivism states that the truth can be identified. This has been replaced more recently by post-positivism, which states that one can never prove a theory is true, because there may always potentially be a counter-example which disproves the theory. Post-positivism also incorporates the concept that the scientific process (e.g., the types of questions that are asked) is affected by pre-determined views of the researcher or society.

postmodernism/poststructuralism: Theoretical perspectives that are characterized by a mistrust of "grand narratives", or theoretical frameworks of social behavior. In place of these grand narratives, postmodernism and poststructuralism emphasize differences and indeterminacy.

reflectivity: The process of identifying one's own subjectivities in order to make them explicit. Identifying these subjectivities throughout the research process and in reports of that research enhances the validity for both quantitative and qualitative research.

situated/situational: All social situations are highly contextual, dependent on the background, interests, and motivation of the participants as well as the particular setting in which the situation occurs. In quantitative research, one of the primary aims of the research design is to eliminate the situatedness as a variable. In qualitative research, the situatedness is recognized as an important factor affecting the phenomenon being studied, and thus it becomes an important part of the research design and report.

theoretical perspective: A theoretical and philosophical approach to understanding and explaining social reality.