Quantitative and Qualitative Research Methods: Bridging the Gap

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Abstract

In the past decades, engineering educators have published interesting research, mainly using quantitative research methods. A few studies have used qualitative research methods, but none has effectively combined both approaches for a more comprehensive understanding of the underlying issues. In this paper, I discuss qualitative and quantitative methods and their theoretical frameworks, and review the work of Tonso, published through the American Educational Research Association. Next, I illustrate how the addition of qualitative research could enhance two important engineering education research studies. Finally I propose a synergistic research model that uses both quantitative and qualitative research methodologies and explore the necessary resources to implement such a model.

I. Introduction

The learning process is fascinating and complex, universal and yet uniquely personal. Within engineering education, we have made great strides in the past 30 years in understanding many fundamentals of learning engineering. We have explored the impact of appropriately structured cooperative learning activities, the connections created through integrated curricula, and many other important advances in the teaching and learning of our discipline. The majority of engineering educational research has been conducted by engineering faculty, and rightly so. However, it usually has been conducted by applying the "scientific method" in one form or another. While this approach yields an important perspective, it is not sufficient for understanding the complex process of human interaction we call learning. In addition, engineering faculty are not accustomed to articulating explicitly the theoretical frameworks or assumptions underlying their disciplinary research. In engineering, laws and theories, such as PV = nRT and light as energy and particle, are implicitly agreed upon by the discipline and therefore not explicitly stated as assumptions (unless that theory is the one under investigation). In education, however, such certainty and agreement are not holistically agreed upon; hence, frameworks, assumptions, perspectives, and paradigms must be stated and their relevance and impact on the study must be discussed. Without such explicitness, informed peer review is impossible.

Our central argument of this paper is that a great need exists for constructing a strong bridge between the discipline of educational research and the discipline of engineering education research. This bridge needs to be bi-directional, as each discipline can provide unique opportunities to the other. Engineering can learn from education how to conduct educational research in a more rigorous, grounded, and relevant way. Education can learn through and be challenged by the unique characteristics of teaching and learning engineering. The bridge also

needs to be multi-modal, as there are many types of collaboration and connection that would be advantageous. One example is more opportunities for engineering faculty to learn educational theory and research methodology. Another example is cross-presentation at conferences such as the American Educational Research Association Annual Conference, the Qualitative Research in Education Conference, the ASEE conference, and the Frontiers in Education Conference. These and other recommendations are discussed more fully at the end of this paper.

In 1993, Barbara M. Olds and Ronald L. Miller presented a paper at the ASEE Annual Conference entitled "Ethnographic Research in Engineering Education."[1] In addition to explaining their conceptions of what ethnographic research is and how it is done, they illustrate their discussion with examples from their study on how students actually undertook the process of planning, conducting, analyzing, and reporting on an open-ended experiment. Although the discipline of qualitative research would consider their study to be a case study and not an ethnography (due to the limitation of the study to one group's cycle through one experiment), it is a very important work that begins building the bridge between engineering education and qualitative educational research.

In 1996, Karen L. Tonso published two papers in the Journal of Engineering Education from her dissertation work in engineering classrooms[2-3]. As far as I can determine, her dissertation is the first in the United States to use engineering education as the "culture" for an ethnographic dissertation project. The significance of her work is discussed in more detail in a later section of the paper.

II. Qualitative Research

Qualitative research can complement, verify, expand, and deepen the conclusions of our traditional quantitative methods. It may also bring them into question for further reflection. Qualitative research can also address many questions and issues for which quantitative methods are not very helpful, including:

- defining the problem when it is not clear, is complex, or is embedded in multiple systems or structures,
- describing unexpected outcomes or side-effects of an intervention,
- identifying issues and concerns in order to design a survey,
- complementing and better explaining survey data, and
- determining why a program is successful.[4]

Good qualitative research is rigorous, well documented, and replicable in the sense that a different researcher could analyze the data and trace the path of the development of conclusions and implications which the original researcher took. Just as quantitative research studies require more than data collection and analysis, qualitative research also requires more than observing and interpreting. The qualitative research design process involves activities such as defining the research questions, identifying the independent and dependent variables (usually called domains), hypothesizing relationships among the domains, and designing data collection and analysis plans. An important distinction between quantitative and qualitative research is the sequence in which these activities are carried out, specifically that quantitative research proceeds in a fairly linear way and qualitative research is intentionally very iterative.

III. Research Paradigms

Nearly all of the research in engineering education has been quantitative research from a positivist, "objectively scientific" paradigm, that is, the paradigm for doing research in science and engineering. There are at least two other paradigms that could be especially helpful in constructing a richer understanding of the teaching and learning of engineering and of the development of capable engineers, namely the interpretive paradigm and the ecological paradigm.

The positivist paradigm is the one upon which the scientific method is founded. A core belief of this perspective is that the researcher is objective, unbiased, and distinct from the participants, and does not influence the data being collected. The focus is on observable behavior, measurement and quantification, and controlling variance and bias. The general goals are 1) generalization of results to subsequent similar events and phenomena and 2) development of universal laws which govern behavior in all settings.

The interpretive paradigm, which is sometimes called the constructivist paradigm, is based on the idea that meaning is negotiated within and between individuals. The researcher and the "subjects" are involved in defining and constructing the research study, which is explicitly informed by their personal experience in interacting with one another. The focus is on elicited meanings for observational behavior, intersubjective understanding, and explaining (rather than controlling) variance and bias. The general goals are 1) comparison of results to similar and dissimilar processes and phenomena and 2) development of workable and shared understandings regarding regularities in human behavior in specific settings. [4]

The ecological paradigm is concerned with the self as defined by social structures representing levels of influence, i.e. what's going on within family, peers, school, work, community, and society. The roles of the researcher and the "subjects" are detached and uninfluenced by personal experience of the research. The focus is on observable behavior and elicited meanings in relation to structures, policies, norms, and behaviors typical of other levels in the system. The general goals are 1) analysis of results to identify relationships across levels in a local situation, 2) development of local predictors influencing individual, group, and social behaviors, and 3) inductive development of regional and larger patterns and laws.[4]

Although research from a positivist perspective can be conducted using only quantitative data, the interpretive and ecological paradigms require qualitative research. The theoretical paradigm does not prescribe what data collection and analysis methods are employed, but instead, influences how they are used and how the results are interpreted. I believe that engineering education research can be strengthened and greatly enhanced by the thoughtful consideration of what theoretical paradigms underlie the research we conduct and how we interpret its results.

IV. The Importance of Local Knowledge

A fundamental concept within qualitative research is local knowledge, which is the collection of tacit knowledge that one needs to fully belong to the local culture. For example, many faculty

members have asked me how to address their students as a group. Some want to use "guys" as a reference to all the people present. Whether or not the women in the group feel included by this term depends on the local knowledge. In the Northeastern United States, "guys" is often used to refer to a group of people that includes men and women. In much of the Southeastern United States, "guys" refers only to that subset of men who are popular and the term "yall" is commonly used to refer to all present. Hence, my answer to their question is "It depends on the local culture." In all research, the researcher's local knowledge is critical in order to assign meaning to words and actions that is consistent with the meaning assigned by members of the group under study.

ABET has recognized the centrality of this notion, although they do not use the same terminology to describe it. In the 2000 Criteria for Accrediting Engineering Programs[5], Criterion 2: Program Educational Objectives states that an institution must have in place "detailed published educational objectives that are consistent with the *mission of the institution*… and a process based on the *needs of the program's various constituencies* in which the objectives are determined and periodically evaluated…" Criterion 3: Program Outcomes and Assessment further states that "The assessment process must demonstrate that the outcomes *important to the mission of the institution and the objectives of the program* … are being measured." (emphasis added) Both of these criteria affirm that each program should determine what is important locally rather than imposing some globally constructed criteria. Some engineering disciplines, such as Industrial Engineering, Ocean Engineering, and Aerospace Engineering, are also subject to the criterion that "faculty must have the responsibility and sufficient authority to define, revise, implement, and achieve program objectives." This additional criterion ensures that the program objectives are not imposed upon faculty by higher administration, but instead are developed and enacted by faculty, which recognizes the local knowledge that faculty may have which the higher administration may not have.

The implication for engineering education research is to recognize that theories of teaching and learning are developed within a particular culture and that our usual ways of categorizing engineering schools may not be fine-grained enough to assure these theories can be transported to other institutions. When we develop a particular intervention, new course, or teaching strategy, we need to not only know if it is effective, but also *why* it is effective. We need to describe the local culture well enough that others can evaluated whether their culture is similar enough to be successful in adapting the innovation. Simply stating that something was developed in a Research I institution with classes of size 50 is not sufficient information. Qualitative research methods, especially interview and focus group methodologies, are more appropriate for answering the "why?" question than are quantitative research methods.

V. Tonso's Dissertation

Karen L. Tonso's dissertation[6] is an important piece of research for several reasons. First, it is the first research study that focuses on the *culture* of engineering education, a concept that is new to most engineering educators. Second, its extensive use of qualitative research methods breaks ground by answering the question "Are qualitative research methods appropriate for studying engineering education?" with a definite "Yes." Finally, the research points to many areas for additional scholarship and research on the engineering educational experience.

The purpose of her dissertation research was to "investigate how women and men student engineers develop an engineering identity (a sense of themselves as belonging in engineering, or not) and the influences of learning and knowledge, gender, relations of power, and equality on identity." Apparently to satisfy many different stakeholders in the research, she used a variety of data collection and analysis methods, including Likert scale surveys, interviews, curricula analysis, participant observation, and elicitation and pile-sorting. In her work, Tonso considered many different and complex issues from the social construction of identity to the interdependence of courses within a curriculum. Her work would be strengthened by focusing on one issue and exploring it in depth, with multiple data sources and analysis methods. In addition, although qualitative research requires self-revelation by the researcher as the primary instrument of data collection, Tonso does not include the expected discussion of how her personal history and perspectives influence her research. Despite these weaknesses, Tonso's dissertation is ground-breaking and important research in the introduction of qualitative research to engineering education.

VI. Atman's Verbal Protocol Analysis

Cynthia Atman and her colleagues are using verbal protocol analysis (VPA) to understand students' design activities.[7] Their analysis is an interesting way to begin to capture the complexity of thought during the solution of open-ended design problems. By videotaping students, who are asked to "think aloud" while individually solving a problem, then coding their speech into phases of a design process, they are developing fascinating graphs of how students transition between the different phases and the amount of time they spend in each phase. Verbal protocol analysis is a way to quantitatively analyze text data. One primary difference between it and ethnographic analysis of text data is the development of the coding schemes. In VPA, the coding scheme is developed by the researchers independently from the data, therefore it may be developed before data collection. In ethnographic analysis, the coding scheme emerges from the data analysis and is therefore done during and after data collection, but never before. This aspect of ethnographic text analysis provides more flexibility to modify and/or expand the coding scheme as needed, keeping it inherently linked to the data as it is collected.

Qualitative research methods could enhance this research program in many different ways. For example, a primary assumption of VPA is that talking aloud will not significantly alter the approach to the activity which the subject uses. Reflective interviews with the students after the design experience could explore the appropriateness of this assumption from the student's perspective. Another example regards the coding scheme developed by the researchers to judge the quality of the student's solution to the design problem. This scheme is not conveyed to the students before they do the design activity. Interviewing the students afterwards about the way that they evaluated potential solutions and ideas would give insight into the student's design process as well. One could investigate whether the conception of quality is congruent between the researchers and the students.

Finally, an interesting qualitative expansion would be to investigate the student's meta-cognition, their image of self as a problem-solver, and how the affective domain influenced their process. One could do this by reviewing the videotapes and resultant graphs with the student while

conducting an in-depth, semi-structured interview. If we are to provide students with effective opportunities for learning design, we must understand issues such as meta-cognition, self-conception, and the affective domain. For a really in-depth study, the researchers could then have the subjects complete another problem-solving session and analyze whether the discussion of the videotapes and graphs seem to affect later problem solving behavior.

VII. Felder's Longitudinal Study within Chemical Engineering

Richard Felder and his colleagues used a standard experimental and control group design to investigate predictors of success or failure in a five semester course sequence in chemical engineering. The five semester sequence was taught by Felder, using active and cooperative learning techniques in addition to lecture. Students completed homework in groups that were stable over each course and worked during class in groups that varied. In a series of five papers, Felder, et. al have reported many interesting findings that may be generalizable to other schools and perhaps even other engineering disciplines. This body of research is very significant in its longitudinal approach and its comprehensive quantitative analysis.

Let us focus on the third paper[8] in the series, which examines gender differences in student performance and attitudes, to consider how qualitative research methods could complement and illuminate the findings of the original study. In their analysis, the authors found that their results were consistent with the current literature regarding gender differences. In particular, they conclude:

> "In summary, the men in the study consistently earned equal or higher grades in chemical engineering courses than did the women, and the percentage of men earning A's in several courses was significantly greater than the percentage of women doing so. Of the students who had intended to major in chemical engineering when they began the first course, the percentage of women who dropped out for any reason after the sophomore year was twice the percentage of men dropping out. The percentages dropping out by the end of the senior year were closer, with relatively more women transferring into other curricula and considerably more men dropping out of school or being suspended. Throughout the period of the study, men who failed a chemical engineering course were more likely than women to repeat the course and remain in the curriculum, while women who failed a course were more likely than the men to switch out of chemical engineering. …
>
> In short, the women in the study entered the engineering curriculum with greater anxiety and lower confidence in their preparation than did the men. They began the first course with higher expectations of themselves, but by the midpoint of the first chemical engineering course their expectations were lower than those of the men, and the disparity persisted throughout the curriculum. The women were more likely than the men to attribute poor performance to their own lack of ability and men were more likely to attribute it to a lack of hard work or being treated unfairly. Conversely, men were more likely than women to attribute success to their ability and women more likely than men to attribute it to outside help. …
>
> In the second semester of their senior year, the men remaining in the experimental course sequence were twice as likely as women to feel that they did more than their fair share in their groups and the women were significantly more likely to feel that their contributions were undervalued or ignored by other group members. … In free questionnaire comments, a number of women commented on their inability to be heard in mixed groups, and videotapes of group work sessions show a tendency of women to be relatively reserved in group interactions."

Following the data analysis, Felder et. al include a section of the paper, entitled "Discussion", in which they examine these two questions:

1) "Why did the women in the study – whose qualifications were arguably better than those of the men when they entered the chemical engineering curriculum – earn lower grades in chemical engineering courses and exhibit progressively lower confidence levels and expectations of themselves as they advanced through the curriculum?"
2) "What support should be provided for women engineering students?"

The authors then provide seven hypotheses, which they claim are suggested by the data and the literature, on the causes of the observed gender differences. They then propose four ways to "support women engineering students", unfortunately framed from the perspective of the women as being deficient and needing change. In the final section, "Summary and Conclusions", they write "We can only speculate on the causes of the observed gender differences in performance and attitudes."

Indeed, relying on quantitative analysis and self-reported, quantitative evaluation of confidence, preparation, and ability does not enable the researchers to answer the question "why" nor does it enable them to draw any reliable conclusions on the causes of the reported differences. In-depth, longitudinal interviews, conducted by a outside researcher considered safe by the students, coupled with direct observation of students' interactions would provide the qualitative data necessary to understand why and how these differences arise, and even to consider in what ways they are "real" or are products of the measurement tools which were used.

In addition, reconsidering this research using the perspective of qualitative research grounded in different theory may lead to very different conclusions. For example, viewing the videotapes of students working together in groups with the perspective of Tannen's communication theory may suggest that the women were not being "relatively reserved" but instead were asserting their ideas and opinions in a style that was different from the male students' style and therefore, not recognized by the students or the researchers. Reviewing the reports of self-confidence and preparation from a cultural perspective of image projection may reveal that the women students are just as internally confident, but display that confidence in ways that are not captured by the forced-choice, self-report instrument used in the study or they simply choose not to display their true level of confidence through that instrument. In addition, taking a qualitative approach to describing self-confidence allows the researcher to move away from a one dimensional continuum of confidence to a more complex, multifaceted, contextual conceptualization of self-image and image projection. In summary, the research done by Felder and his colleagues is very critical and foundational to a better understanding of the educational system. However, if it is not complemented by qualitative research, it may lead to incorrect conclusions and ineffective recommendations for change.

VIII. Synergistic Model

Figure 1 illustrates a synergistic model that combines quantitative research methods and qualitative research methods. The model recursively alternates between theory development and exploration via quantitative or qualitative methods. The decision of which method to use is guided by the primary question at hand. Exploring why, exactly what, or how something occurs indicates the need for qualitative methods that allow the in-depth exploration of a piece of the

puzzle. The outcomes of this exploration include "thick" description of time, place, action, interactions, context, and meaning, which then provide the understanding for further theory development and refinement. Exploring prevalence, majority opinions, and normative assessment points toward quantitative methods as most effective. An across-the-board quantitative analysis can provide comparisons to others in the same population, to others in a different population, to others in the past, or to self in the past. These comparisons then generate more ideas and more questions, leading to further theory development.

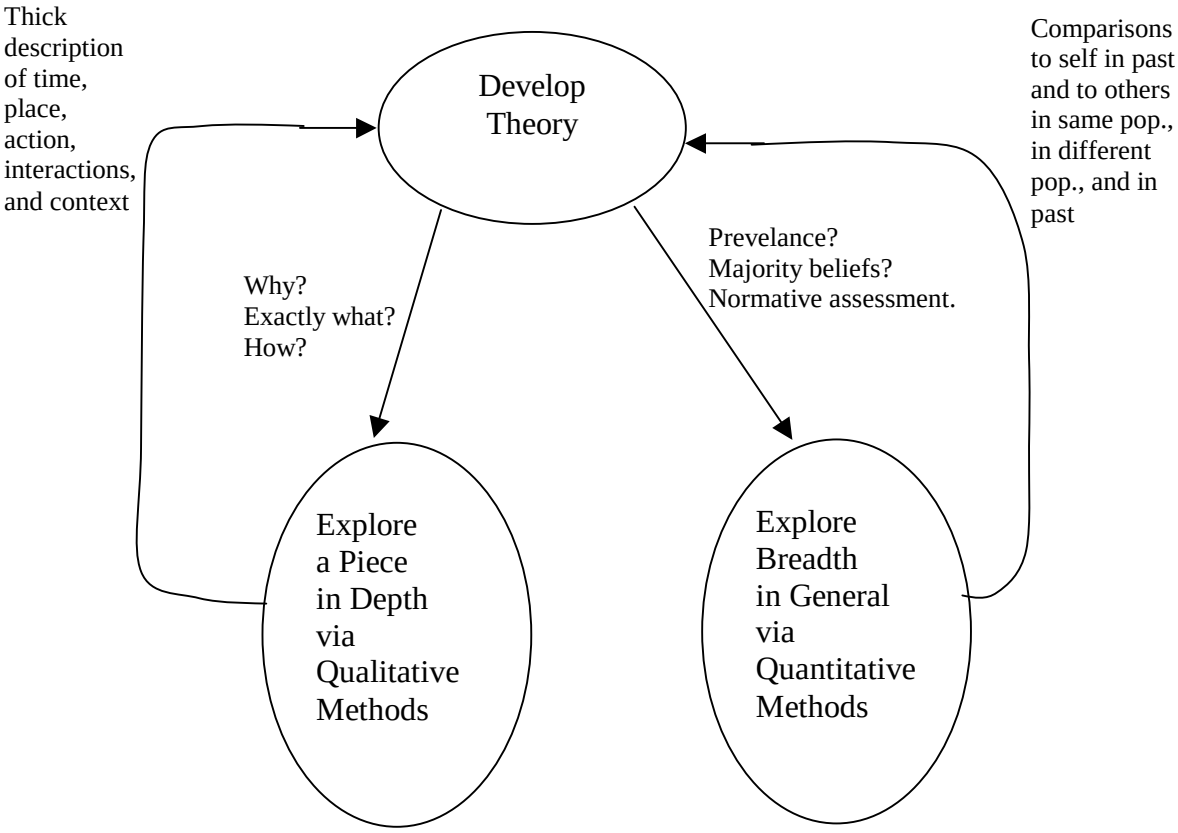

Figure 1: A Synergistic Model

Resources Needed for Implementing the Model

In order to implement this recursive, synergistic model, a research team would need sufficient resources of personnel, materials, time, and space. These resource needs different somewhat from the resources required by purely quantitative research in engineering education. If it is to be adopted, then funding agencies, tenure and promotion committees, and institutional research

offices may need to change their expectations of faculty who conduct engineering education research.

First, let us consider the personnel resources needed. The model implies that a research team would need qualitative researchers, quantitative researchers, and engineering content specialists. Of course, multiple roles could be played by each person in the team. In addition, each team member would need a general understanding of qualitative and quantitative research methods and the theoretical perspectives which underlie the research design. Another important people resource is the group of study participants. In a project which includes qualitative research, the participants, usually students, must be willing to develop trusting relationships with the interviewers and observers who are collecting the data. The time commitment and personal involvement to be involved in such a study are much greater than one in which they simply fill out a survey and allow access to their records. Finally, this synergistic model requires entrée into classrooms, office hours, student team members, and other locations which are implicitly considered somewhat "private" spaces. The faculty member whose classroom is a data collection site must be fully supportive of the study and all data collection methodology.

The material and financial resources required to implement the model includes support for videotaping, audio taping, and most importantly, transcription of the tapes. The videotaping could be done by the audio/visual services unit of the college, by the research team or by students employed by the study. The transcription could be contracted out to a commercial firm, done by student employees, or done by the researchers. Although having the researchers transcribe the tapes has the disadvantage of taking their time away from theory development, it has the advantage of immersing them in the data, making analysis easier. In addition, these tapes must be permanently stored, along with the field notes, journals, data analysis notes, etc. In traditional quantitative research, the data is stored electronically, with the original paper surveys being disposed of after data entry and analysis is complete. However, the trustworthiness of qualitative research depends on all the data and notes being available for auditing by another researcher, so 'hard copies' must be retained.

Finally, conducting research using this model would generally require more than three years to design the study, collect the data, analyze the data, and iterate through the process several times. Since many granting agencies have a three year time span for funded research, the work may need to be divided into different phases or funding agencies could grant support for longer time frames, dependent on acceptable progress at key points. In addition, time for face-to-face discussions is also necessary. This model is dependent upon the researchers (and often, participants) negotiating the meaning of words and actions, both their own and within the data. Such negotiation is usually not necessary with the 'scientific method', but are critical to qualitative research.

IX. Ideas for Further Bridging

Building a bridge between two very different landscapes is a complex and challenging task, but it is one that engineers are uniquely suited to do. I offer the following suggestions for ways to begin constructing a bi-directional, multi-modal bridge between engineering education research and qualitative education research.

First, we need multiple opportunities for engineering faculty who are interested in conducting educational research to learn about qualitative research methods and about fundamental education concepts such as epistemology, philosophy of education, theoretical frameworks, and psychology of learning. In addition, opportunities to study in the fields of anthropology, women's studies, philosophy, cultural studies, and sociology would be important. The format of these studies should span the gamut from workshops and short courses to immersion experiences. The immersion experiences could include sabbatical leave to join an education department, master's programs specifically designed for faculty who already have a Ph.D. in their discipline but want to do research in education, and joint appointments between colleges of engineering and colleges of education. Immersion experiences are important because the current system of faculty picking up bits and pieces without an overall framework or philosophy focuses too much on particular pieces and prevents us from seeing the interactions between pieces. As engineers, we know that a systems approach is as necessary as the individual, detailed analyses of the components.

Next, as engineering education researchers, we need to collaborate with other organizations, such as the American Educational Research Association (AERA), the American Association of Higher Education (AAHE), WEPAN (the Women in Engineering Programs Advocates Network), and the Professional and Organizational Development Network (POD). Members of these organizations could team with engineering educators to develop the workshops and short courses in a way that would help them be more successful with engineering faculty. In addition, we should be presenting our research at their conferences and inviting their presentations at our conferences, especially at the Frontiers in Education conference. Although the formal presentations are important, let us not overlook the critical networking, collaborating, and learning that happens during informal discussions in the hallways between sessions and over meals during the conferences. I would also like to see more engineering education research proposals include members of these organizations to strengthen the diversity of perspectives within the research and therefore strengthen the outcomes of that research.

Finally, I believe that, as a community of scholars, we need to construct more explicit guidelines for reviewing the research methodology of one another. The peer review processes for the ASEE and FIE conference are changing and growing stronger, as is the review process for the Journal of Engineering Education. Yet, I still see many papers where the methodology is not sound and/or the assumptions behind the methodology are not articulated. For example, many studies use Likert scales with options labeled from 1 "strongly agree" to 5 "strongly disagree", producing ordinal, categorical data. Often this data is analyzed using t-tests for detecting statistical difference. However, the t-test is only appropriate for interval data, where the numbers have real numerical value and are not just convenient labels for concepts. Seldom do authors describe any initial descriptive analysis of the data, such as contingency tables. As researchers, we need to keep in mind the difference between statistical significance and practical significance, asking the question, "Is this reported effect real and how is it manifested?"

X. Conclusions

In conclusion, qualitative research methods have much to offer to engineering education research. They allow the consideration of questions which quantitative methods alone can not answer and they give a rich, contextual understanding of the process of learning. The theoretical foundations of any research study on education need to be articulated and the implications discussed. In particular, the local knowledge that impacts the study must be carefully documented so that others may determine the applicability of the work to their own situation. Several authors have begun exploring the application of qualitative methods within engineering education. In this paper, I also suggest ways that two well-known, funded studies could be enhanced through the addition of qualitative methods.

Instead of advocating a complete switch to qualitative research, I propose a synergistic model that incorporates both quantitative and qualitative research methods. This model enables a researcher to benefit from the advantages of each and to capitalize on the compounding effects of their interaction. However, applying this model does require more human capital, more material resources, and more time.

Powerful resources exist in the academic education community to enable engineering educational research to continue to develop and mature as a discipline. Individuals and professional associations, who are based in education, are available to co-develop workshops, immersion experiences, and collaborations to the mutual benefit of both disciplines. As individuals and as a community we need to begin building a bridge between our two landscapes to allow each side to learn from the other.

Acknowledgements

I would like to thank Barbara Olds for many thoughtful conversations about the potential of qualitative research methods in engineering educational research, my EPRS 8500 classmates who consistently challenged my thinking as this paper developed, and Sheryl Gowen, my advisor, for her constant support and insightful feedback.

Bibliography

1. Barbara M. Olds and Ronald L. Miller, "Ethnographic Research in Engineering Education," *Proceedings of the 1993 American Society for Engineering Education Annual Conference & Exposition*, Session 3630, p. 2048-52.

2. Karen L. Tonso, "Student Learning and Gender", *Journal of Engineering Education*, April 1996, Vol. 85, No. 2, p. 143-150.

3. Karen L. Tonso, "The Impact of Cultural Norms on Women", *Journal of Engineering Education*, July 1996, Vol. 85, No. 3, p. 217-225.

4. Margaret D. LeCompte and Jean J. Schensul, *Designing & Conducting Ethnographic Research*, 1999, Altamira Press, Walnut Creek:CA.

5. Engineering Accreditation Commission, "Criteria For Accrediting Engineering Programs", Revised 3/18/2000. Baltimore, MD.

6. Karen L. Tonso, "Constructing Engineers Through Practice: Gendered Features of Learning and Identity Development." Unpublished doctoral dissertation, University of Colorado, Boulder (Dissertation Abstracts International, 9800565).

7. Cynthia J. Atman and Jennifer Turns, "Studying Engineering Design Learning: Four Verbal Protocol Studies," to appear in *Knowing and learning to design: Cognitive perspectives in design education*, C. Eastman, M. McCracken, and W. Newstetter (Eds.), Elsevier: New York.

8. Richard M. Felder, Gary N. Felder, Meredith Mauney, Charles E. Hamrin, Jr., and E. Jacquelin Dietz, "A Longitudinal Study of Engineering Student Performance and Retention. III. Gender Differences in Student Performance and Attitudes," *Journal of Engineering Education*, April 1995, Vol. 84, No. 2, p. 151 – 163.

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