

Emerging Methodologies in Engineering Education Research

JENNIFER M. CASE AND GREGORY LIGHT^a
University of Cape Town, Northwestern University^a

BACKGROUND

Methodology refers to the theoretical arguments that researchers use in order to justify their research methods and design. There is an extensive range of well established methodologies in the educational research literature of which a growing subset is beginning to be used in engineering education research.

PURPOSE

A more explicit engagement with methodologies, particularly those that are only emerging in engineering education research, is important so that engineering education researchers can broaden the set of research questions they are able to address.

SCOPE/METHOD

Seven methodologies are outlined and for each an exemplar paper is analyzed in order to demonstrate the methodology in operation and to highlight its particular contribution. The methodologies are: Case Study, Grounded Theory, Ethnography, Action Research, Phenomenography, Discourse Analysis, and Narrative Analysis. It is noted that many of the exemplar papers use some of these methodologies in combination.

CONCLUSIONS

The exemplar papers show that collectively these methodologies might allow the research community to be able to better address questions around key engineering education challenges, such as students' responses to innovative pedagogies, diversity issues in engineering, and the changing requirements for engineering graduates in the twenty-first century.

KEYWORDS

data collection methods, research methodologies

INTRODUCTION

Across this issue, a compelling case has been presented for the significance of engineering education research, as well as the ongoing need for development of this scholarly field. This article focuses on methodology as a crucial area with which researchers need to grapple in order for the quality and scope of research to continue to develop. It is argued that methodological decisions need to be more explicitly represented in reports of research and that researchers need to consider a broad range of methodological options, in particular those methodologies that could be considered to be “emerging” in engineering education research, in order to be able to answer the research questions at hand.

What is methodology? For many education researchers, not only in engineering education, there is a perception that methodology is a synonym for methods. It has been noted that many Ph.D. thesis chapters entitled Methodology are nothing more than a listing of

the data collection and data analysis methods used (Burton, 2002). This is not necessarily wrong; many such terms have multiple and conflicting meanings across the literature (cf. Crotty, 1998), but in this article we will argue for the value of using a broader definition of methodology, referring to a theoretical justification for the methods used in a study (Burton, 2002; Clough & Nutbrown, 2002).

Methods have received substantial attention in the engineering education literature, particularly in this journal in recent times (Borrego, Douglas, & Amelink, 2009; Koro-Ljungberg & Douglas, 2008; Olds, Moskal, & Miller, 2005). Following the work of Olds et al. (2005), who draw a distinction between experimental and descriptive research designs, Borrego et al. (2009) set out the terms of the debate focusing on the distinction between quantitative, qualitative, and mixed methods studies. They observe that engineering educators at a recent conference lamented the lack of qualitative studies in the engineering education literature yet reflected reviewers' preference for quantitative methods, particularly classroom experiments. In one exchange they note that "there was even evidence that participants perceived a setting to be unworthy of study if a control group is not available" (p. 61). They note that "engineering educators who have been trained primarily within the quantitative tradition may not be familiar with some of the norms of qualitative research" (p. 56) and they suggest that some reviewers of archival journals may suffer from the same limitation. Borrego et al. (2009) make the crucial point that a wider range of data collection methods will allow researchers to address a wider range of research questions and their article gives a comprehensive overview of quantitative and qualitative methods, as well as a discussion of mixed methods studies which use both of these. A further contribution to this discussion has been the paper by Koro-Ljungberg and Douglas (2008) who present an analysis of *Journal of Engineering Education* (JEE) articles which use qualitative methods. In addition to noting the low frequency of such articles, they show that these articles seldom provide an adequate justification of why these methods are used or integrate these substantially within their broader research design and theoretical orientation. These articles provide our departure point which locates the debate on research methods within a broader discussion of methodology.

DEFINING THE DOMAIN OF METHODOLOGY

Crudely, methods are best understood as the tools and procedures we use for our inquiries and methodology is about the framework within which they sit.
(Cousin, 2009, p. 6)

Burton (2002, p. 4) provides a practical and accessible definition of what a discussion of methodology will entail for a particular study:

- why the researcher chose that focus;
- why the study was designed by the researcher in that way;
- why alternatives were rejected;
- what were the questions the researcher was asking; and
- how the researcher ensured that confidence could be felt in the data gathered and in their analysis of those data.

While arguments for using a particular methodology are unique to a study, the methodologies are not. Although they are subject to modifications particular to the study, methodologies are generally located in a range of established methodological positions.

Clough and Nutbrown (2002, p. 31) note that an engagement with methodology allows the researcher to locate their research design within a particular “tradition of enquiry.” Cousin (2009) makes the following important observation:

Although many methods are friendly to particular methodologies and to particular research contexts or questions, there is not always a straightforward association between method and methodology. This is because different people might use the same methods with quite different values and aims in mind. (p. 5)

Crotty’s (1998) positioning of methodology makes the relationship between methodology and broader theoretical orientations very explicit. He locates methodology within four key elements of the research process:

- Methods: the techniques or procedures used to gather and analyze data related to some research question or hypothesis.
- Methodology: the strategy, plan of action, process, or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes.
- Theoretical perspective: the philosophical stance informing the methodology and thus providing a context for the process and grounding its logic and criteria.
- Epistemology: the theory of knowledge embedded in the theoretical perspective and thereby in the methodology. (p. 3)

From this outline it can be seen that methodological choices are not separate from choices of theoretical perspective and epistemology. In order to discuss methodology, we thus need briefly to consider theoretical perspectives with their embedded epistemological commitments. Koro-Ljungberg and Douglas (2008) note that in contrast to the positivist and post-positivist perspectives which are hypothesis-driven and center on establishing cause and effect relationships, there are a range of other perspectives, grouped under the term “situational perspectives,” that engineering education researchers should consider for possible application in their studies. Situational perspectives include interpretivism, critical theory, and poststructuralism, and, although they each have slightly different objectives, they collectively differ from positivism and post-positivism in that they are focused on delivering understandings of particular situations or experiences. They are generally inductive in approach and allow for insights and findings to emerge throughout the data collection and analysis process. Participant selection, rather than being driven by the need for a statistically representative sample, is usually purposive. It thus follows that statistical generalizability is typically not an aim of this research; rather the researcher aims to produce generalizability in the context of the study, with the onus on the reader to determine transferability to other contexts (Lincoln & Guba, 1985). It thus follows that the means for assuring research rigor in these perspectives tend to rest on a different epistemological foundation. Instead of the traditional tests for validity, the researcher has a range of means of assuring the integrity of results, what Lincoln and Guba refer to as “trustworthiness.” The focus shifts from traditional measures of objectivity towards “confirmability,” the assurance that research findings are rooted in contexts and persons apart from the researcher, and that they did not merely arise in the researcher’s imagination (Lincoln & Guba, 1985).

One of the chief differences between the three perspectives which Koro-Ljungberg and Douglas (2008) group under the term situated perspectives is the ends towards which they direct their research. Interpretivism generally aims towards increased understanding of

people's subjective experiences. Critical theory is explicitly directed towards critique of social inequities and power relationships with the ultimate goal of facilitating social change. Poststructuralism and postmodernism look to deconstruct the taken for granted "truths" or "grand narratives" through which society operates.

It has been noted earlier that the engineering education research community has tended to focus the debate on the difference between qualitative and quantitative research methods. From the discussion earlier one can see that a much more significant distinction exists between the different theoretical perspectives which are marshaled to justify both the methodologies and methods employed. In fact, it is crucially important to note that although the tenets of the situational perspective may favor a qualitative approach, quantitative methods can often form a significant part of such a study. Furthermore, as noted by Koro-Ljungberg and Douglas (2008), qualitative research is often used in studies which reside in a positivist perspective. In this respect, the use of mixed methods is less an issue of bringing qualitative and quantitative methodologies together, than a logical, pragmatic response to the demands of the particular research questions identified and the methodological approach employed to address them.

WHY FOCUS ON METHODOLOGY?

Koro-Ljungberg and Douglas (2008) have demonstrated that the issue of methodology has received limited explicit discussion in the engineering education literature. The same has been noted in other areas, for example, in the field of mathematics education research (Burton, 2002). The lack of an explicit discussion of methodology in these fields is detrimental in a number of respects. Firstly, it is often hard to know what to make of particular research findings, how to interpret them, and what status to ascribe to them. More importantly, what often happens when methodological discussion is limited is that methodology is tacitly accepted as a given, meaning that one methodology is implicitly assumed to be the right one. As such, our focus on methodology in this paper is, in the first instance, largely a call for making the whole question of methodology more explicit in engineering education. Secondly, while accepting as Cousin (2009, p. 2) notes, that "randomized control trials remain a gold standard for some researchers," we also agree with her that educational research, including the growing field of engineering education research, is "a big playground where no one methodology needs to hog the best swing."

There is not a right methodology or even a right set of methodologies. The choice of methodology (with its underlying theoretical perspective and its related set of methods) is determined by the kinds of research questions that one wishes to ask. One's choice of methodology will constrain what questions one can ask, and conversely certain research questions can best be addressed with certain methodologies. It will thus be quickly seen that if a research community limits itself only to particular methodologies it is likely that the research findings it is able to generate will also be limited.

In this issue, Borrego and Bernhard (2011) note that classroom-based studies of student learning have been the core focus of engineering education research in the U.S. While these studies have delivered central and significant insights to the field as summarized in the article in this issue by Litzinger, Lattuca, Hadgraft, and Newstetter (2011), it has limited the ability of the community to grapple with broader issues including diversity, the public image of engineering, and the impact of globalization. Drawing on the central European tradition of engineering education research, they note the importance for the

research community to also grapple with issues of the aims of engineering education and to ask direct questions of what is taught and why it is taught. The focus on testing the effectiveness of classroom innovations has furthermore limited the ability of the community to address deeper issues in student learning, as also outlined in this issue in the contribution by Johri and Olds (2011). We would argue that collectively these concerns reflect the importance of research studies that are able to go beneath the surface of common sense ways of thinking about engineering education. If we are to find ways to significantly address the challenges of the twenty-first century we need an educational research field that can extend its domain of questions to those that are patently needing to be asked.

The relationship between research questions and methodology is usually not unidirectional but is rather two-way or what might be described as “dialectical.” One might start out with some idea of what one wishes to research, identify an appropriate methodology and then go back to the research questions and refine them, and so on. Cousin (2009), moreover, suggests that researchers would do well to move away from a traditional linear way of thinking about the research process where a researcher first produces a literature review, then formulates the research question, then collects data, then analyses it, and finally writes it up. She notes that “Increasing numbers of researchers recognize that all of these activities need to be dynamically linked and continually enlivened by an engagement with a wide reading” (Cousin, 2009, p. 3). Research questions need to be informed by education theory, and thus another dialectical relationship exists between education theory and methodology.

We have focused on the theory that is needed to inform research methods (theoretical perspective, etc.), rather than on the education theory that is also a crucial part of the research process. Here we are referring to examples of theories of learning, theories of teaching, theories of learning environments, and so on. These are the typical domain of the literature review and the choice of education theory is typically reflected in the research questions, for example, to uncover the threshold concepts in a particular domain of engineering knowledge, or to determine the approaches to learning used by a group of engineering students. Once again, this is a two-way relationship, and thus a choice of methodology will typically have implications for the kind of education theory that will be relevant to a particular study.

EMERGING METHODOLOGIES IN ENGINEERING EDUCATION RESEARCH

Rather than attempt to outline all possible methodologies that can be adopted in engineering education research, this article focuses on methodologies that are promising but as yet not well represented in engineering education research, with uneven distribution across different global regions. In that sense they can be described as “emerging,” particularly for JEE audiences, although they might be well established in education research more generally. These are:

- Case Study
- Grounded Theory
- Ethnography
- Action Research
- Phenomenography
- Discourse Analysis
- Narrative Analysis

Each of the following sections will consist of two parts. First, a brief description of some defining features of each methodology will be offered focusing in particular on the

arguments used to justify the use of the set of methods. The second part of each section will present an engineering education research paper which exemplifies this methodology. Here the focus will be on the research questions and associated theories that were used in the study as well as the ways in which the methodology is linked to these. The selection of exemplar papers has been guided by the requirement that these are recent pieces of engineering education research published in the international literature which offer useful illustrations of how the methodology has been applied. They have also been selected as exemplars to demonstrate the wider range of research questions that the community might address if it broadens the range of methodologies with which it engages. It is worth noting that while some of these articles have been published in engineering education journals, others have been published in more generic education journals. Quality engineering education research is published across a wide range of fields and the community would do well to be alert to this broader literature.

CASE STUDY

A case study can be described as an in-depth study or examination of a distinct, single instance of a class of phenomena such as an event, an individual, a group, an activity, or a community (Abercrombie, Hill, & Turner, 1984; Shepard & Greene, 2003). Case study as a methodology can be used as motivation for the validity of findings emerging either from an analysis of a single case or across multiple cases. Flyvbjerg (2001) identifies a range of different strategies that can be used in the selection of cases, depending on the nature of the research question involved. Options include choosing a set of cases with maximum variation in order to explore a range of different settings, or identifying unusual cases which allow the researcher to probe particularly problematic situations, or using critical cases which allow for logical deductions of the type “If this holds for this case, then it will hold for all other cases.”

Case study as a methodological approach has frequently been critiqued for its assumed limitations. Not surprisingly, these critiques are concerned with the issue of generalizability of the empirical results attained by case study. Flyvbjerg (2001) considers these critiques to rest on essential misunderstandings of case study methodology. These include the positivist view that “general, theoretical (context independent) knowledge is more valuable than concrete, practical (context dependent) knowledge”; that it is not possible to develop “general propositions and theories” from a single case study and, as such, a “case study cannot contribute to scientific development” (p. 221). The concrete, context dependent nature of the knowledge which case studies unearth, on which these critiques focus, however, is precisely the source of its methodological strength. Case study can therefore be particularly appropriate to address research questions concerned with the specific application of initiatives or innovations to improve or enhance learning and teaching. The new knowledge here takes into consideration the particular idiosyncrasies of the institution, its resources, teachers and students, as well as its overall culture. This can be contrasted with a more positivist kind of study aimed at evaluating the general applicability of an educational intervention—characterized, for example, by a more traditional randomized controlled study—primarily focused on “proving” the general effectiveness of the intervention. As Hans Eysenck (1976) aptly noted, “sometimes we simply have to keep our eyes open and look carefully at individual cases—not in the hope of proving anything, but rather in the hope of learning something!” (p. 9).

Exemplar paper. Magin, D. J., & Churches, A. E. (1995). Peer tutoring in engineering design: A case study. *Studies in Higher Education*, 20(1), 73–85.

This paper describes the use of a case study to investigate the impact and success of an innovation designed and implemented in response to an educational dilemma which arose from a very specific set of institutional and historical circumstances. In 1992, the School of Mechanical and Manufacturing Engineering at the University of New South Wales commenced a program of conversion from traditional pencil-and-paper engineering design subjects to a program in which design teaching was to be based on computer graphics, employing a state-of-the-art solid modeling designer's package.

In the first year cohort, the number of students vastly out-numbered the number of workstations available for the students. As such, the department decided to run two separate courses in parallel, a traditional pencil-and-paper course for three quarters of the 170 students and a workstation based course for the remaining quarter. With the arrival of new workstations the next year, all of the now second year students had access to work stations. The dilemma was that three quarters of them would need intensive training with the new software. It was decided the most efficient way to do this training would be for the students who had workstation experience in the first year to peer tutor those who did not have the experience. During the first four weeks of the course, the students worked in groups of approximately one peer tutor for three tutored students.

A general research question drove the case study: What was the perceived enhancement in learning, for both the tutored students as well as the peer-tutors? In addition the researchers were interested in the impact on the conditions for learning during the period of peer tutoring. Finally, they were also interested in the reactions of the teaching staff to the program. The case study employed multiple methods to obtain data including informal observation of the program and tutoring groups, open-ended surveys of the tutored students and peer tutors, and interviews with tutor-groups, students and teaching staff.

The results of the study showed that both the tutored students and the peer tutors found the experience useful for learning with respect to the three elements of the package on which the evaluation concentrated. The analysis of the data also indicated that the conditions for learning facilitated by the program compared very favorably with the more traditional teacher-led approaches. For example, when compared with the alternative form of teaching which the students were offered (assistance from a teacher when required) about half the students preferred the peer tutoring compared to less than 5% who preferred the alternative of teacher assistance. Particular conditions which the students identified as helpful were: enhanced interactions in terms of more individual assistance and immediate response to queries; better learning climate in terms of being more relaxed, easy, and friendly with a peer; and a more empathetic relationship with peers. Finally, interviews with the teaching staff indicated that they felt the program had worked well and that the tutored students had progressed with the software at least as well as the students who had had direct instruction the year before.

The case study approach in this particular research project not only showed that the program had achieved the learning outcomes which the original dilemma had highlighted; the study was also able to identify additional pedagogical results (with respect to the learning conditions which the peer-tutoring added) which resulted in planned changes for second and third year cohorts of students going forward.

GROUNDED THEORY

Grounded theory was established in a seminal piece of work by Glaser and Strauss (1967) and was one of the first methodological positions put forward that supported the use of qualitative data in social research. It has since been described as “a general methodology for developing theory that is grounded in data systematically gathered and analyzed” (Strauss & Corbin, 1994, p. 273). At the heart of grounded theory is the idea that theory is generated from the data at hand, rather than already existing theory being used in the analysis as is generally common in education research. In order to accomplish this, researchers are required to keep an open mind at the start of the research, “colored as little as possible by expectations based on existing theories” (Taber, 2000, p. 470).

The constant comparative method is a central data collection method in the grounded theory methodology, even though it has also been subsequently utilized in many other areas of qualitative research. This method provides a clear step by step outline of a process for analyzing qualitative data. In the first stage of this procedure, also termed “open coding,” initial categories are developed by grouping similar incidents together. During the coding of each incident it must be carefully compared with other incidents previously coded in the same category. In the next stage of the analysis, termed “axial coding,” a further refinement is done on the categories and their properties by stepping back and testing all incidents coded in a category with the properties of that category. The categories are also compared for overlap and examined for possible relationships among categories. The endpoint of data collection is reached through a process termed “theoretical saturation,” which occurs when additional data collection and analysis does not substantially change the findings.

Strauss and Corbin describe theory as “plausible relationships proposed among concepts and sets of concepts” (Strauss & Corbin, 1994, p. 277), and stress that theory building is very different to description. Two foci in developing theory are discovering patterns and identifying processes.

Another aspect of the grounded theory methodology is that data collection and analysis are tightly interwoven. The initial theories emerging from the data are used to direct further data collection. One possibility in this respect is to use theoretical sampling, where additional research subjects are selected as the study proceeds in order to explore issues that have arisen.

In its pure form, grounded theory tends to find limited application in education research, where researchers often find it productive to use existing theoretical constructs in their analysis. However, as a mode of research for challenging preconceptions and allowing for alternative conceptualizations it has enormous strength. In an analysis of student learning in engineering education, Case and Marshall (2004) used a form of grounded theory to direct a study which ultimately identified a new approach to learning prevalent in these contexts, the procedural approach, which had not been found in previous studies in different disciplinary contexts.

Exemplar paper. Jonassen, D., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education*, 95(2), 139–151.

Given the central role of problem solving in the engineering workplace, and current efforts in engineering curricula to better prepare graduates for the world of work, this study aimed to identify the key attributes of workplace engineering problems. This research question thus required that the researchers go into the workplace and find out what was

happening. A practical way of doing this was to interview engineers about their work. Semi-structured interviews were conducted with over a hundred practicing engineers, and interviewees were required to focus on a single job or project that they had completed at some point in their career, and then to describe a typical problem that had needed to be solved.

The researchers did not want their research findings to be circumscribed by existing thinking on this topic and thus they opted for a grounded theory methodology. However, they also needed the work to be informed by prior research and thus a particular grounded theory methodology termed “analytic induction” was employed.

Each interview was transcribed and contributed towards a case library of engineering stories. A narrative methodology (see below for further discussion) was incorporated to justify the data focus on stories. The method of constant comparison was used to identify categories or themes and stages of both open and axial coding were employed. Twelve themes were identified, which collectively describe important characteristics of workplace problems. It was noted that workplace problems are frequently ill-structured, with constraints and unanticipated problems emerging during the process. However, it was also found that these ill-structured problems often comprised aggregates of smaller, well-structured problems. This seemed at the heart of engineering problem solving, being able to identify these smaller problems and address them in turn. It was further found that ill-structured problems frequently have multiple, conflicting goals and the task of the engineer was essentially to identify the goal with the highest priority. Another theme was that engineering problems are frequently solved in multiple ways. Often engineers have to use their professional experience and judgment to choose the most efficient way for solving a problem.

A rather surprising theme in these findings is that the success of a solution is rarely judged using engineering standards which largely center on a technical analysis of risk and failure: the most significant criteria for judging success tend to involve satisfying the client, completing the job on time or under budget. In a similar vein, it was noted that most constraints were not engineering related but most frequently related to time. A further theme is that problem solving tended to be distributed amongst team members, where different team members contribute their particular strengths to solving the problem. A related finding of the study disclosed that much engineering problem solving required extensive collaboration. It was also found that engineers tend to rely primarily on experiential knowledge, especially in applying theoretical knowledge to real world situations. Echoing the ill-structured problem characteristics mentioned initially, a further theme referred to the idea that unanticipated problems are often encountered along the way. It was found that engineers use multiple forms of representation of the problems with which they are dealing, with the most common form of representation being a drawing. Finally the authors note that the engineers they interviewed recommend an increased focus on communication skills in the engineering undergraduate experience. The findings are used to support a call for engineering curricula that are more problem-based, and take into account these characteristics of real problems.

ETHNOGRAPHY

The genesis of ethnography as a research method is generally attributed to work in anthropology and goes back at least a hundred years to the work of Malinowski who stressed

the importance of “grasp(ing) the native’s point of view” in his work (Stocking, 1983). Ethnography can also trace its ancestry to early developments in sociology, in particular the Chicago School which argued that observation, later participant observation, was critical for developing a full understanding of an environment. Central to this early ethnographic research was the idea of closely studying first hand how people live in particular social situations. Drawing on this seminal work, ethnography has, according to Hammersley and Atkinson (2007), more recently generally come to be understood as:

... a particular method or set of methods ... (which) involves the ethnographer participating, overtly or covertly, in people’s daily lives for an extended period of time, watching what happens, listening to what is said, asking questions—in fact, collecting whatever data are available to throw light on the issues that are the focus of the research. (p. 1)

The demands of coming to a rich understanding of people’s day-to-day lives within a social environment presents substantive challenges to ethnographers, particularly with respect to gathering and interpreting the data in terms of the meanings which the members, themselves, attach to their own world (Bryman, 2001). This is particularly challenging given the demand to write up these meanings for readers—academics and policy makers—who live in different social cultures. In addition, the constraints of doing educational research do not afford today’s ethnographer the luxury of living with the people they are studying, and certainly not for years. They are more likely only to be able to follow their lives closely and carry out their fieldwork over many months.

The methods which ethnographers use to collect data during their fieldwork are usually diverse and multiple. In addition to the researcher’s own field notes which may include records of discussions, chance conversations, interviews, overheard remarks, observational notes, the researcher may also employ audio and video recordings and quantitative data gathered from surveys or structured observation.

The nature of ethnographic research means that the quality of the research may be difficult to judge given more traditional evaluation criteria. While there are no firmly established standards, Richardson (2000) suggests five general criteria. Two criteria concern judgments of whether or not the research makes a substantial contribution to our “understanding of social-life”; and whether it presents a “credible account” of the reality which it attempts to describe (p. 254). In addition, she raises criteria related to the work’s “aesthetic merit” (is it aesthetically successful?) and its “emotional impact” (does it move me?). Finally, she draws attention to the importance of the researcher’s self-awareness of their own role in the research.

Exemplar paper. Stevens, R., O’Connor, K., Garrison, L., Jocuns, A., & Amos, D. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education*, 97(3), 355–368.

In a longitudinal study, this paper seeks to identify critical dimensions of the experience of becoming an engineer over four years of undergraduate study. In this effort, the paper seeks to disclose the characteristics which describe both how a student makes him or herself into an engineer and how he or she is made into an engineer with respect to the formal and informal educational experiences related to academic engineering programs. To address this question, the authors employ what they call a “person-centered ethnography” (p. 355) which focuses on the individual within the particular social context. Indeed, their goal is described as “recovering the person” within the wider social context in which they are becoming an engineer.

To address this question the researchers follow students in four differing institutions of higher education, which are contrasted in terms of their size (large and small institutions), location (urban and suburban), their research profile (intensive or not), and their structure (public and private). Students at all four of the schools were interviewed using multi-hour ethnographic interviews during each of the four years. In addition, at the Large Public University, further interviews were conducted with the students and the students at this school were also accompanied on their daily activities during each of the four years. The paper primarily focuses on the data from this school, supplemented with data from the other schools.

The results of the paper are given in the form of a three dimensional conceptual framework describing the phenomenon of becoming an engineer. These inter-related dimensions are: Accountable Disciplinary Knowledge, Forming an Identity as an Engineer, and Navigating through Engineering Education. These three dimensions and their relationships are described in detail and illustrated with concrete descriptions of student experiences, often in their own words. Importantly, the ethnographic methodological approach taken in this study reveals qualitatively different ways of understanding these three dimensions than might have been traditionally expected. Rather than, for example, engineering knowledge in terms of a stable curriculum of knowledge to be acquired over time, this ethnographic study disclosed the changing contextual nature of what counts as disciplinary knowledge. In the first years what counted was static knowledge transmitted in traditional, pre-requisite lecture courses in which students were expected to give back the right answer on exams. In later years however, what counted shifted more to open-ended problems, assessments of team work, and so on. There were also changes in the expected learner relationship to data, from data provided in laboratories to the expectation of generating one's own data. Not surprisingly, this was often accompanied by feelings of frustration and anxiety.

Similar changes were also revealed in the ways in which students began to form personal identities with engineering. The paper stresses the double-sided character of identification, both that students need to identify with engineering and that they need to feel accepted by engineering. Differences between universities in which students were admitted into engineering programs immediately and those that were not, presented bigger obstacles for the latter to forming an identity with the discipline. Likewise, concrete changes across the years had a substantive impact on identification: upper-level students began to be given the "keys to the clubhouse," so to speak, which included things like increased access to laboratories, to online networks, to disciplinary lounges, and so on. As is clearly documented in one of the two in-depth case studies provided at the end of the paper, navigational flexibility which permits informal experience and knowledge gained through personal contacts and external work opportunities also plays a significant role towards becoming an engineer.

ACTION RESEARCH

The term "action research" was first used by Kurt Lewin while he was at MIT in the 1940's with a special focus on social action. It is a critical educational research methodology looking to foster change in social practices in the social situations in which they take place "within everyday, natural contexts rather than within controlled settings" (Cousin, 2009, p. 150). The aims and benefits of action research are strategic improvement of practice. This critical focus on continuous improvement raises the second defining feature which

distinguishes action research from other educational methodologies: it is almost entirely determined and conducted by its various practitioners. Indeed, improvement occurs through the active engagement of the practitioners. As such, action research is research *with* subjects, not *on* them, an idea that, as Cousins notes, “reverses the conventional scientific understanding of objectivity” (Cousin, 2009, p. 151).

Carr and Kemmis (1986) describe three types of participatory inquiry which have been described as action research. They differ in terms of the degree to which the practitioners or participants are the principal researchers. In *technical action research* the researcher facilitates the process and establishes and judges the standards for improving educational practice. The participants mainly contribute at a technical level. *Practical action research* also focuses on improving practice, but participants participate more fully and reflectively in the research to develop their practical understanding. Finally, *emancipatory action research*, encourages the full participation of participant-as-researcher to critically explore the effectiveness of practice in the social and organizational constraints in which it is situated. In this mode, action research employs a critical research methodology involving issues of equity and power relationships.

In addition to being participative and focused on improvement, Kember (2000) also describes action research as being reflective, systematic, and cyclical. In its design, methods, and realization, it consciously and deliberately sets out to improve, enhance, and realize practice through actions informed, but not constrained, by research and theory. It is flexible, open to change necessitated by experience and circumstance, and it is subject to the practitioner’s critical and rational practical judgments. Kemmis and McTaggart (1988, p. 7) describe the implementation of this strategic action as a continuous cycle of four moments:

- A plan of action to improve what is already happening;
- Action to implement the plan;
- Observation of the effects of action in the context in which it is occurs;
- Reflection on these effects as a basis for further planning, subsequent action and so on, through a succession of cycles.

Action research of this kind can be a particularly effective methodology for engineering faculty who are not only interested in systematically researching their own educational practices but also in implementing substantial personal and social change in their practice. Nevertheless the use of action research is still relatively rare in engineering education research. Using cases from architecture, engineering, and construction, Hartmann, Fischer, and Haymaker (2009) use ethnographic action research to study the implementation of information systems, and in three case studies Mejía, López, and Molina (2007) report on the effective use of action research to create “Collaborative Engineering Environments.”

Exemplar paper. Jørgensen, F., & Kofoed, B.-L. (2007). Integrating the development of continuous improvement and innovation capabilities into engineering education. *European Journal of Engineering Education*, 32(2), 181–191.

This paper reports on an action research project which is broadly situated in the context of ever-increasing demand for and proliferation of courses concerned with equipping a new generation of engineering students with knowledge about innovation. In this program, continuous improvement and innovation (referred to as CI), rather than simply being topics on the curriculum, were used towards the building of student capabilities for continuous improvement and innovation. The initial goals of the research were “... to use the principles of CI to improve issues the students themselves identified as problematic in their study program while supporting the students’ development of basic CI capabilities.”

In light of the program's focus on improving student capabilities, it was felt that an action research approach was most appropriate. Moreover, bringing in students as active participants in the cyclical nature of the research, including planning and generating ideas and solutions, meant that the research began to engage them in continuous innovation as well as continuous improvement. The paper thus provides an analysis of building student CI capacity in terms of both continuous innovation as well as continuous improvement.

The students who participated in the research were all in the first year of a three-year Global Business Development (GBD) program at a Danish university. The program takes a problem-based and project-based approach with students working in six groups of 5–7 participants. The projects are developed with an actual local company. Each group has an advisor and elects a student member to a steering committee. A faculty coordinator meets with the steering committee and oversees the overall educational quality of the program each semester, including providing online feedback to and from teachers and students. The coordinator for the semester when the research took place was the principal action researcher and first author of the paper. The six student members of the steering committee enthusiastically agreed to be participant co-researchers.

The research was conducted through a series of six steps of activities. In the first activity, the main researcher met with student participants to discuss the research goal—improving the GBD program using CI principles—and potential areas for improvement. The students also met alone with their fellow students to get their input. In the second step, two areas of improvement were identified: communication and projects. The communication issues centered around providing first-year students with more practical information on the GBD program and on the feedback communicated by the steering committee coordinator. Critical comments about individual teachers tended to be censored, which the students felt eliminated their chance of communicating teaching problems. With respect to projects the students identified a mismatch between company goals of solving real problems and the learning outcomes of inexperienced first year students.

In steps three and four of the action research, the focus was on generating potential solutions, negotiating and developing those solutions with students, faculty, and administrators, and implementing the solutions. Very briefly, the solutions consisted of planning, developing, and implementing an informational seminar, conducting an unofficial steering committee meeting to discuss previously censored sensitive issues, and replacing first year projects in companies “with a written or video-recorded case that encompasses all of the learning objectives” (p. 187). Steps five and six of the research consisted of evaluation of the results and on reflecting on and modifying the improvements. The student researchers conducted reviews and gathered feedback from members of their groups and summarized them for the steering committee. The unofficial steering committee had only partial success in helping students have some impact on teaching. The confidential minutes of this meeting were sent to the formal program study board for review. Finally the replacement of actual company projects with multi-media cases was found to be highly successful.

Significantly, as a result of the action research project, the students asked if the study could be extended and a process of continuous improvement was enacted. Additional problems and solutions were identified. This resulted in the development of a process of continuous innovation for the students which included establishing an online student network for planning and sharing ideas for improvement. Finally, the study reported important ongoing changes in the six participating students engaged in the action research. Four followed up their experiences with further projects on CI and innovation and all six developed a collaborative plan to continue to work together to discover further ways to support

improvement. Perhaps even more significantly was the emancipatory impact which the program indicated arose as a result of this research. As one student put it, “now it feels like we have so much more power because we don’t let limitations and constraints get in our way” (p. 189).

PHENOMENOGRAPHY

Phenomenography was first developed as a specific research methodology by researchers in Sweden in the 1970s. Its primary focus is the investigation of the different ways in which phenomena, or aspects of a phenomenon (such as specific concepts), are experienced or understood within particular educational and learning contexts; phenomenographic research is searching for a comprehensive record of the *variation* in the experiences of people in such contexts. Marton and Booth (1997) describe this methodology as seeking “the totality of ways in which people experience . . . the object of interest and interpret it in terms of distinctly different categories that capture the essence of the variation...” (p. 121). This totality of different ways is often referred to as the “outcome space.” The outcome space is not a record of individuals, but a description at the collective level, of different categories of experience.

Phenomenography resembles other forms of inquiry such as *phenomenology*, for instance, with a focus on the individual’s point of view rather than the researcher’s or a community’s, and on the use of data collection methods such as semi-structured interviews, and related textual and visual materials. It is, however, unique in two respects, which have implications for the particular sampling procedures and data analysis in this methodology. First, rather than looking for common shared experiences of a phenomenon, as is the case with *phenomenology* (Van Manen, 1990), phenomenography focuses on the ways in which learners *differ* (Marton, 1989). It is therefore important to maximize the potential variation of experience in the sample of individuals interviewed, ensuring the sample is fully representative of potential experience with respect to the phenomenon under consideration: not all the highest performing students, for instance, nor all the poorest performing students. The second key difference with *phenomenology* is that rather than making the phenomenon the subject of the research, as *phenomenology* does (Van Manen, 1990), phenomenography takes experience of the phenomenon as its unit of analysis. The data collected from individuals thus needs to be pooled together and analyzed (in a careful iterative process) to identify a set of distinctive categories (and the critical dimensions of variation which differentiate these categories) by which the full collective experience can be described. The analysis aims at identifying the fewest, logically related, categories required to describe the totality of variation discerned in the pool of experience.

The identification of different conceptions, moreover, makes phenomenography particularly well suited for the design of educational learning objectives, pedagogical strategies, assessments, and evaluations (Micari, Light, Calkins, & Streitwieser, 2007). Phenomenographic work provides program developers with a profile of the variation in experience across all of the participants in the program. Phenomenographic research has been used primarily in education, including engineering education, to investigate variations in the ways students understand important concepts such as energy in solution processes (for example, Ebenezer & Fraser, 2001), size and scale in nanoscale science and technology contexts (Swarat, Light, Park, & Drane, in press), and transient responses in student problem

solving contexts (Carstensen & Bernhard, 2009). It is also beginning to emerge in other engineering contexts as well. For example, it has been used to identify conceptions of competent work among engineers in an auto manufacturing company (Sandberg, 2000), and conceptions of the value of information-technology (IT) research among IT researchers and practitioners (Bruce, Pham, & Stoodley, 2004).

Exemplar paper. Booth, S. (2001). Learning computer science and engineering in context. *Computer Science Education*, 11(3), 169–188.

This paper has been selected to exemplify the use of phenomenography in engineering education research because it describes phenomenography and the theory of variation underpinning it in three different ways: in terms of strengthening a broader new pedagogical culture in higher education; in the pedagogical reform of a new Computer Science and Engineering program; and in the evaluation of the impact of the program on student learning experiences.

The paper locates the empirical study which is at the heart of this study—the analysis and description of the student experiences of the reformed course—within the broader context of what it refers to as a growing tendency in higher education “away from a traditional transmissive pedagogy ... towards a pedagogy that can broadly be characterized as constructivist” (p. 169). The two pedagogies are contrasted in terms of different theories of teaching and learning, the former assuming a passive student mind which teaching needs to fill up through the transmission of knowledge, while the latter assumes an understanding of student learning as active, and concerned with the responsible construction of understanding, which teaching facilitates through the construction of appropriate conditions for such learning. Phenomenography is construed here as constitutive of the broader constructivist philosophy.

In keeping with this broader philosophy, the pedagogical design of the reformed computer science course is described as specifically reflecting a view of learning related to the phenomenographic tradition: learning on the course “is seen as becoming able to experience (or see, conceptualize, understand) something (a phenomenon, a theory, a principle, a field of practice) in a particular way, in line with the goals set” (p. 176). Learning here, however, not only includes the acquisition, application, and understanding of key information on the course topics, but also acquiring motivations or a “relevance structure” for learning which include an understanding of the relevance of the course to the program overall, to future engineering studies and to social issues. Towards this goal, the reformed course offers at the outset:

... a whole picture—however vague and incomplete at the outset—that encompasses the overall goals of the program. This (comprises) ... a number of situations in which groups of students have to work to reveal aspects of the world of computer engineering. They are to start actively on the process of discerning new parts in the whole and relating them to one another and to the whole. (p. 178)

The student groups, led by a graduate tutor, were purposely constructed to provide students with a range of experiences of variation, in the themes they work on, in the different ways group members understand and speak about the themes, in the different experience of group processes etc., in order to facilitate awareness of unconsidered aspects of computer science and/or ways of learning.

The phenomenographic approach to the evaluation of the new program consisted of interviewing a diverse selection of 16 students from a range of different types of groups, including both successful and less successful groups, all male and mixed gender groups, and groups with similar aged and those with different aged members. Results of the phenomenographic analysis focused on the variation in both student experiences of relevance structure, and on learning in groups. With respect to the former, three qualitatively distinct experience of the relevance of the course were identified: Those pointing "(A) nowhere at all, or (B) inwards to its parts in isolation, or (C) outwards to the coming education and/or professional field" (p. 179). Three qualitatively distinct categories of experience with respect to learning in groups were also identified: "(A) Learning in isolation within the group; (B) Learning as part of a distributed effort; and (C) Learning as part of a collaborative effort" (p. 182).

It is worth mentioning, to pick up a point made by Eysenck in the discussion of case study (earlier), that this evaluation-based phenomenographic research is not so much aimed at "proving" the effectiveness, or not, of a program but rather in illuminating and learning about the program. The results suggest that neither the students nor the tutors were fully grasping the constructivist goals of the course and that further reform of the course was necessary. Indeed, an important insight learned was that student ability to gain richer experiences of relevance was not going to surpass the experience of relevance of the tutors themselves. Further training with tutors was conducted in the subsequent years. Similarly, the variation in student experiences of learning in groups suggested that simply putting students with different perspectives in groups was not sufficient for facilitating collaborative learning. They need to engage in meaningful collaborative tasks that require recognizing their peers as sources of knowledge and enlightenment.

DISCOURSE ANALYSIS

Discourse analysis is a methodology that emerged from the field of linguistics but which is now well established across a range of education research areas. Some of the key approaches to discourse analysis are those by Fairclough (2003) and Gee (2005). The data that forms the focus for this methodology are actual instances of language in use, for example the transcript of a classroom discussion. Hicks (1995) emphasizes that the term discourse always refers to communication that is socially situated. The significance of an analysis of discourse is that it allows us to get insights into the beliefs, values, and world views which are held by participants since these are always reflected in the use of discourse.

In the context of engineering education, it is important to note that discourse not only comprises written text; it also includes mathematical equations, graphs, figures, verbal exchanges, and so on. The discourse of being an engineer will involve the practice of design to solve real world problems, and this includes collecting and analyzing data, using empirical laws and correlations, doing mathematical calculations and modeling, as well as presenting one's results to a range of different audiences. In short, discourse comprises everything that describes the academic and professional activities which characterize engineering practice. Over time, this community has developed shared ways of talking about and understanding the issues and practices that matter to them. From this point of view, successful learning involves using a discourse in order to participate in this

community (cf. Northedge, 2003). This way of describing learning is at the heart of the methodological justification on which discourse analysis is based.

From this description of discourse analysis it can be seen that this methodology is not limited to studies of student reading and writing, as might have previously been assumed, but has wide applicability to a range of research questions in engineering education. A central question concerns the role that language plays in student learning as well as the role it plays in social interaction. Importantly, a discourse perspective reminds us that the activities of academic discourse are never neutral and can pose particular difficulties when they clash with other discourses in which the student is engaged; learning a new discourse involves taking on a new identity (Gee, 2001). Discourse analysis usually requires data in the form of transcriptions of utterances and practices—pieces of discourse—recorded during the event, for example, classroom discussions, student conversations, and so on. It can also productively be applied to analysis of interviews.

Discourse analysis has been extensively used across a range of disciplinary contexts in both school and university education, with highly productive applications in mathematics and science (for example, Airey & Linder, 2009; Sfard, 2001). It is starting to be used in engineering education research and a recent paper by Allie et al. (2009) draws on discourse theory to put forward a position on how to improve student learning in engineering education. In research with third-year engineering students, Case and Marshall (2008) demonstrate an application of Gee's concept of Discourse models to identify the implicit theories that students use to make sense of their learning experiences.

Exemplar paper. Kittleson, J. M., & Southerland, S. A. (2004). The role of discourse in group knowledge construction: A case study of engineering students. *Journal of Research in Science Teaching*, 41(3), 267–293.

This paper reports on a study of mechanical engineering students in a capstone design course at a large research university in the western part of the U.S. This course had been recently reworked to explicitly combine aspects of numerical simulation and experimentation in response to industry concerns that these key elements of the design process had been traditionally neglected.

Engineering design requires an engagement with the underlying physical phenomena relevant to the project, and thus a key part of the group design process involved grappling collaboratively with these concepts. This study focused specifically on this aspect of the design project, termed here “concept negotiation.” Another important dimension of this study was in understanding what really happens in project-based pedagogies, which are increasingly popular in engineering education. Previous studies had shown that the collaborative work that is necessary in these contexts is often not easy for students to undertake. In summary then, the research question guiding this project was described by the authors as a quest to understand the way in which groups of students construct knowledge in an engineering design project.

In looking for an appropriate methodology to guide this study, which by definition would need to explore what was happening in groups during this process, the researchers selected Gee's method of discourse analysis since it is not only directed towards analyzing conversation, but also focuses on why things are happening in particular ways. At what they termed the “microlevel” of group process they needed to identify instances of concept negotiation in the discourse. At the macrolevel, identifying Discourse¹(s) in operation, they were able to identify what factors might inhibit or enable concept negotiation. It is worth noting that

¹Gee uses a capital 'D' i.e. 'Discourse' to signify this macro-level.

these methodological decisions are explicitly presented in this journal paper; something not uncommon in the *Journal of Research in Science Teaching* where it was published.

For the study, the researchers focused on one group of students in depth. In justifying the choice of one team, they argue for this study as an exploratory case study. This is a good example of the way in which researchers often can productively combine methodological positions to support and guide their study. In motivating for their particular choice of a team, the researchers point out that this was a team where it was considered most likely for concept negotiation to have to occur, given both the particular project brief (analyzing fluid dynamics and heat transfer in automotive defrosters) and that it was a relatively large group of students compared to others in the class.

The data collected for this study consisted of transcripts of the laboratory sessions where the group was working on its design project, semistructured interviews with the students, and field notes from participant observations of the class.

The findings of this study need to be considered in the light of what this methodology generated that other methodologies might not have been able to surface. From a detailed analysis of transcripts of the group processes in action, it was found that instances of concept negotiation were, in fact, surprisingly rare. For example, in a typically laboratory session with a duration of 86 minutes and 41 seconds, only 7 minutes and 43 seconds was identified as concept negotiation. The majority of the time was taken up with what they termed “off-task talk,” “administrative talk” and “procedural talk,” the latter dealing with the mechanics of the task, for example on how to set up an experiment.

A significant dimension to this study is the identification of the discourses at play which led to such a limited use of concept negotiation in the group. It was found that, despite the lecturer’s attempt to promote collaborative group work, students held a set of beliefs which seemed to focus on using group work for maximum efficiency and therefore dividing up work amongst the different group members and not working collaboratively. These discourses were directly related to students’ views of what it was to be an engineer. These beliefs stand in contradiction to the intentions of this teaching innovation and thus severely constrained the kind of learning that could take place in this course.

NARRATIVE ANALYSIS

Narrative methodology has its origins in the field of literature studies, but has found applicability across a range of social science fields including education. In fact, building on the work of John Dewey which points to the deep interrelationships between experience, education, and life, some narrative researchers have argued that narrative methodology is particularly applicable to education research: “In its most general sense, when one asks what it means to study education, the answer is to study experience” (Clandinin & Connelly, 1998, p. 154). Narrative methodology is especially suited to this task since it is focused on investigating the way people experience life.

What do we mean by the term “narrative”? Polkinghorne (1995) notes that although the commonsense term “story” is used by some researchers it carries with it connotations of falsehood or misrepresentation. Oliviera (2005) makes the important point that not all pieces of prose are automatically narratives. Hinchman and Hinchman (1997, p. xvi) define narratives as “discourses with a clear sequential order that connect events in a meaningful way for a definite audience, and thus offer insights about the world and/or people’s experiences of it.”

An influential education scholar, Jerome Bruner (1986), has argued that “narrative cognition” is a particular form of human knowledge, distinct from what he terms “logical-scientific” knowledge. Telling stories is a fundamental human activity, a means by which we represent ourselves to others and make sense of our lives. Narrative methodology focuses on collecting and analyzing these stories in order to understand human experience. In the context of engineering education, narrative methodology can help us understand how students experience their education contexts.

Polkinghorne (1995) develops a useful distinction between two modes of analysis that can be used within a narrative methodology. The more usual form of analysis he terms as “paradigmatic” analysis where the researcher attempts to identify common themes across the various narratives that have been collected as data. This has links to the method of constant comparison associated with grounded theory analysis mentioned earlier. Polkinghorne (1995), however, points to the utility of an alternative approach he terms “narrative analysis” where each narrative is considered on its own merits. A key activity in this approach is in organizing the various data elements present into a coherent account of that person’s development.

Gergen (1994) has pointed out that there are different orientations to the study of people’s narrative accounts. Cognitivist approaches have tended to emphasize the individual, while Gergen advocates a position which focuses on the links between the narrative and the broader culture. He describes self-narratives as “forms of social accounting or public discourse” (p. 249). This approach has some similarities to the methodology of discourse analysis discussed earlier where the study of instances of discourse is linked to the broader discourses operating in society.

There has been considerable use of narrative inquiry in educational research, but mostly focusing on teacher education. Some recent examples are Volkmann and Zgagacz’s (2004) study of the experience of a graduate teaching assistant in an inquiry-based physics course, and Clark and Linder’s (2006) study of a South African township high school teacher’s experiences of introducing innovations in her physical science classroom. In engineering education this narrative analysis has been adopted in a recent study analyzing data from one South African engineering student in order to develop a more in-depth understanding of the experiences of students from educationally disadvantaged backgrounds (Marshall & Case, 2010).

Exemplar paper. Walker, M. (2001). Engineering identities. *British Journal of Sociology of Education*, 22(1), 75–89.

In this study, Walker seeks to address the question of why the participation of women in engineering programs remains relatively low, even though there have been dramatic shifts in society with regard to gender roles, including an equalizing of educational performance especially at the school level which has been described as “closing of the gender gap.” Furthermore, women engineering students have been noted to generally outperform their male peers in their academic studies.

In order to address this question, Walker needed to explore the ways students, both male and female, are experiencing engineering studies, and the identities that they develop in this regard. A narrative methodology was thus chosen, and she interviewed a small group of electrical engineering students at a research-intensive university in the U.K. The interviewees included both male and female students, at a range of academic levels including undergraduate, postgraduate, and postdoctoral studies. The postdoctoral students were interviewed individually but the other students were interviewed in groups, in order to allow for students to feel more comfortable with the interviewer and for the generation of

richer material as they interacted with each other. In line with the narrative methodology the interviews were relatively unstructured and unrushed (mostly 2 hours in length) in order to obtain in-depth accounts of experience. In justifying her choice of a narrative form of methodology, Walker argues that “narrative interviews ... expand and stretch complexity rather than reducing it, as generalizations are challenged by particular accounts” (p. 76).

A key finding of this study was that in narrating their experiences, female engineering students emphasized their differences from their other female peers and projected identities that associated themselves with their male engineering peers. These can be termed “resistant identities,” but Walker’s analysis goes on to show that underneath the surface these in fact do not challenge the norm and that dominant stereotypes of gender roles remain intact. Thus, the female engineering students are seen by their male peers as more hard-working and organized rather than as more academically talented. Male students can be seen to make use of the nurturing roles taken on by women in the way group work is structured. This situation is further played out when students apply for work, with female students tending to underestimate their skills and male students doing the opposite. Walker also notes the way in which these dominant notions of masculinity and femininity within engineering education tend to constrain the opportunities for those male students who would prefer not to follow their traditional stereotype. A particular instance is given of a male postdoctoral student who took on a caring role with regard to his wife who had severe health problems; his supervisor was not able to accommodate this within his expectations of how a student’s personal life should interact with his studies.

This brief outline of some of the key findings in this study demonstrates well that the narrative methodology allowed for a research approach that was able to go beneath the surface of what is happening in a domain of engineering education: this analysis provides a compelling understanding for why the numbers of women in engineering program remains limited. For as long as the context requires that women need to take on these resistant identities it will only be a small group of women who will opt for this choice. Furthermore, in examining this issue from both female and male experiences, the study shows that the current situation is not only limiting for females but also for males.

DISCUSSION AND CONCLUSION

Good research is not about good methods as much as it is about good thinking.
(Stake, 1995, p. 19)

This article took as a departure point that a more explicit engagement with methodological issues is needed in engineering education research. By methodology we refer not just to the methods of data collection and analysis that are used, but to a theoretical justification for the use of these methods and the kinds of knowledge that they are able to generate. The article has outlined seven methodologies which were deemed to be “emerging” in the context of engineering education research. Case study is a methodology which argues for the significance of knowledge generated in particular contexts. This is a methodology that underpins much research in the interpretive and critical theoretical perspectives and is frequently combined with other methodologies. Grounded theory focuses on the generation of knowledge from empirical data without the use of *a priori* theory. This methodology has been used to inform the design of studies in a wide variety of research situations.

Ethnography is a methodology which favors long term engagement with the social context under investigation and which aims for the generation of “rich descriptions” of the lives of the research participants. Although, in its pure form in education research, ethnography is employed in very specialized investigations, aspects of this methodology have been productively applied to a range of research contexts. Action research is aimed towards the improvement of practice. This research is characterized by engaging the main participants in the research as co-researchers active in the research design, implementation, and analysis. Phenomenography seeks to uncover the different ways in which a phenomenon is experienced by people in a particular context. This methodology is well established in research on student learning in higher education. Discourse analysis and narrative analysis are both forms of linguistic analysis but focus their attention on different kinds of “texts.” Discourse analysis is focused on instances of socially situated communication and seeks to link these to the underlying cultural ideas which they represent. Narrative analysis centers on the “stories” which people generate as they seek to make sense of their experiences.

For each of the methodologies identified as “emerging” in engineering education and featured in this paper, an exemplar paper was featured. In addition to providing a concrete illustration of the use of a particular methodology, collectively the exemplar papers demonstrate a number of important points. First, as has been noted, a number of studies explicitly describe themselves as drawing on more than one methodology. Thus, the study by Jonassen et al. (2006) on the nature of engineering workplace problems, which was used to exemplify grounded theory, also made reference to narrative methodology to support the data collection of engineers’ “stories.” Moreover, it might be noted that in different ways, all of these exemplar studies draw on case study methodology in that in-depth data is collected from particular contexts: for the Kittleson and Southerland (2004) study it is one group of engineering students working on a design problem, both Booth (2001) and Jørgensen and Kofoed (2007) focus on a particular program, Walker (2001) interviews a small number of engineering students at one university, and so on. Borrego et al. (2009) note the prominence of classroom-based studies in engineering education; the study by Magin and Churches (1995) featured as an exemplar of case study research is a useful example of how explicitly engaging with methodology can allow researchers to generate useful knowledge from classroom innovations; in this case the incorporation of peer tutoring in an engineering design course.

The focus for this paper on emerging methodologies rests on an argument that in expanding our methodological range we might be able to expand the kinds of research questions that can be addressed in engineering education research. Here, the exemplar papers point nicely to some of these new directions. We need to understand in more depth what actually takes place in real engineering classrooms, particularly when we are implementing innovative pedagogies: Kittleson and Southerland (2004) used discourse analysis to investigate what happens when students work on a team assignment; Booth (2001), using phenomenography, is able to provide an explanation of why a program reform in computer engineering is not achieving its desired ends; Magin and Churches (1995) are able to look closely at peer tutoring and what it might achieve. With this broader range of methodologies we are also able to get deeper into some of the ongoing challenges in engineering education regarding student retention and diversity. Using narrative methodology, Walker (2001) is able to identify the reasons why the numbers of women in engineering remain stubbornly low. Stevens et al. (2008) provide a compelling understanding of the intertwined challenges which face engineering students and the ways in which institutions can facilitate or hinder their growing identification with the discipline. Jørgensen & Kofoed (2007) use action research to engage students in a continuous innovation and improvement process in their own

program. Finally, we need to be able to look to the demands of the twenty-first century engineering workplace, and Jonassen et al. (2006) show how grounded theory methodology can be used to provide in-depth and contextual answers to these research questions.

The emerging methodologies that have been highlighted and the exemplar papers that have been examined here only scratch the surface of possibilities for further development in engineering education research. We suggest that a further deep engagement with issues of methodology is likely to yield a dramatic growth in the range of research findings that can be generated in the field.

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AUTHORS

Jennifer Case is an associate professor in the Department of Chemical Engineering and assistant dean for Academic Development in the Faculty of Engineering and the Built Environment at the University of Cape Town at the University of Cape Town, Private Bag, Rondebosch, 7701, South Africa; jenni.case@uct.ac.za.

Gregory Light is the director of the Searle Center for Teaching Excellence and an associate professor in the School of Education and Social Policy at Northwestern University, 627 Dartmouth Place, Evanston, Illinois 60208; g-light@northwestern.edu.