Quality in Interpretive Engineering Education Research: Reflections on an Example Study

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Abstract

Background The emerging discipline of engineering education research is increasingly embracing a diverse range of interpretive research methods, whose adoption is characterized by a lack of coherent ways to conceptualize, communicate, and judge the quality of interpretive inquiries. Yet fields that have traditionally employed these methods do not offer a consensus about research quality.

Purpose This article presents reflections on challenges to research quality in an example interpretive engineering education study, and offers a quality framework that emerged from this study as a coherent, discipline-specific view on interpretive research quality.

Design/Method Analysis of the prior study of engineering students' competency formation by the author(s) is combined with a synthesis of the literature from the broad intellectual traditions of the interpretive paradigm to inform the development of a theoretical framework of research quality.

Results Drawing on the engineering metaphor of quality management, we propose a systematic, process-oriented framework of research quality along two dimensions: a process model locates quality strategies throughout the research process, and a typology systemizes fundamental aspects of validation (theoretical, procedural, communicative, and pragmatic) and the concept of process reliability to explicate quality strategies in their fundamental contribution to substantiating knowledge claims.

Conclusion The quality framework provides a way to develop and demonstrate overall research quality in the interpretive inquiry by shifting attention away from assessing the research quality of a final product. Rather, the framework provides guidance to systematically document and explicitly demonstrate quality considerations throughout the entire research process.

Keywords interpretive methods; research quality; validity

Introduction

Engineering education research is an inherently interdisciplinary endeavor (Baillie, Ko, Newstetter, & Radcliffe, 2011; Borrego & Newswander, 2010) undertaken by a community of engineers and social and educational researchers with diverse and often contrasting disciplinary and epistemological perspectives (Borrego, 2007a). An ongoing discourse in the community consequently concerns appropriate research methods (Borrego & Bernhard, 2011;

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Borrego, Douglas, & Amelink, 2009; Douglas, Koro-Ljungberg, & Borrego, 2010; Leydens, Moskal, & Pavelich, 2004) and ways of conducting research of acceptable quality (Borrego, 2007a; Moskal, Leydens, & Pavelich, 2002; Streveler & Smith, 2006). In this context, Borrego (2007b) asserts that "the field of engineering education has not yet developed its first paradigm," with "paradigm" being defined as "consensus with regard to . . . standards of rigor" (p. 6), among other aspects.

Addressing this preparadigmatic nature of the field, this article considers questions of research quality in interpretive approaches to engineering education research. This topic is particularly contentious for two reasons. First, fundamental assumptions underlying interpretive research approaches are unfamiliar to many researchers with backgrounds in engineering (Borrego, 2007a; Case & Light, 2011; Streveler, Borrego, & Smith, 2007), and, second, fields that more traditionally embrace interpretive methods do not offer a broad consensus about ways of establishing research quality (Flick, 2006). Discussions of research quality in these fields are extremely diverse and span proposals of both traditional and reinterpreted criteria (Cohen, Manion, & Morrison, 2000; Maxwell, 1992) and also suggestions for various alternative approaches (Lincoln & Guba, 1985; Tracy, 2010). In a good summary of the development and current state of the debate, Anfara, Brown, and Mangione (2002) situate their own proposal of strategies to ensure interpretive research quality in the context of a "considerable controversy about standards for the design and conduct of [qualitative educational] research." One aspect of their work that is relevant for the process-oriented quality framework proposed here, is their focus on "assessing and publicly disclosing the methodological rigor and analytical defensibility of qualitative research" (p. 28). This view is mirrored by Cho and Trent's (2006) suggestion of "a recursive, open process in qualitative inquiry" (p. 321). While providing strategies to improve and communicate research quality in specific phases of research, both proposals point to the need for a cohesive and systematic view of how research quality is achieved with respect to the overall inquiry.

This article uses as an example study our earlier interpretive engineering education study (Walther, Kellam, Sochacka, & Radcliffe, 2011) to explore and make explicit our methodological choices and underlying assumptions relating to research quality. In navigating the challenges to research quality encountered in the study, we drew on conceptions and strategies suggested in the literature but experienced a lack of coherent and systematic ways of conceptualizing interpretive research quality in the context of the overall inquiry. This article draws on the interpretive research literature and reflections on our example study to develop a systematic, process-oriented quality framework for interpretive research quality based on the engineering metaphor of quality management.

The article is structured as follows. The first section introduces the guiding quality metaphor, defines key concepts, and provides an overview of the example study. The next section introduces a rich account of one theme from the data that is used to illustrate the theoretical discussion throughout this article. Using this example theme, the article then explores fundamental assumptions about the nature of the empirical reality under investigation (ontology) and the ways in which we can know about this social reality (epistemology) as they were manifested in our example study and which form the foundation for the development of the process-oriented quality framework. This framework is subsequently introduced through a process model of interpretive research as its first dimension that locates concrete quality strategies within a specific inquiry. The second dimension is a typology of five fundamental processes to substantiate knowledge claims that explicates the specific function of quality strategies in their contribution to overall research quality. After establishing the model as it emerged from the reflections on the example study, we situate this proposal in active the current discourse in engineering education research and explore implications for broader research practice.

Background

An Engineering Quality Metaphor

To address the issue of the lack of a coherent and systematic way of conceptualizing research quality throughout a specific inquiry, we developed a process-oriented framework of research quality that was found useful in the example study; we offer it here as a starting point for a discussion of interpretive research quality in the engineering education research context. While procedural views of research quality have been hinted at previously (Anfara et al., 2002; Cho & Trent, 2006; Lincoln, 1995), such proposals have remained on the programmatic level and leave room for suggestions of concrete, contextual implementation (Flick, 2007). In this context, the engineering subdiscipline of quality management (Deming, 1982) offers a useful, process-oriented view of quality that has been operationalized, for example, in the notion of Total Quality Management (Cottman, 1993; Zairi, 1993).

We draw on the concept of quality management as an engineering metaphor to conceptualize a framework of interpretive research quality in engineering education. We contend that quality management not only is a potentially useful bridging paradigm for researchers from an engineering background, but also comprises qualities that make it inherently suitable for framing notions of research quality and associated quality strategies in engineering education research studies.

Engineering quality management processes were developed in the area of product manufacturing and transfer the concern for quality from an assessment of the final product to a process of continuous improvement throughout the production process involving all stakeholders (Cottman, 1993; Zairi, 1993). Quality management, with an emphasis on process, offers a way of thinking about research quality that is applicable to a wide range of settings, can incorporate and contextualize existing strategies, and, at the same time, acknowledges that quality cannot be defined or achieved as an absolute measure. These characteristics make this concept suitable for the flexible, inclusive, and contextual view of research quality we develop here. We do not wish to evoke the rigid, prescriptive, and mechanistic views of quality management that can be associated with this concept, either in manufacturing or in engineering education research. Consequently, the quality framework we propose is intended neither as a prescriptive model that is limited to a particular type of inquiry nor as a comprehensive view on research quality. Rather, it is intended as a novel way of considering interpretive research quality across a wide range of engineering education inquiries and as a framework to be adapted and expanded in sustained discourse within the research community.

Working Definition: Interpretive Research

As a basis for developing the quality framework from the methodological reflections on the example study, the following presents a working definition of interpretive research and research quality as they relate to the intellectual traditions of educational research and to current discussions in the engineering education research community.

Interpretive research is used here to broadly describe social inquiry that derives knowledge claims from the interpretation of lived experiences of individuals or groups. As such it is a subset of qualitative research that assumes that social reality is locally and specifically constructed (Lincoln & Guba, 1985) and emphasizes the reflective subjectivity of making sense of, and deriving knowledge claims about, this reality. Interpretive approaches thus depend on the researchers' philosophical position rather than on their methodological orientation and can entail a range of particular methods. This definition aligns with the intended openness of the proposed quality framework to include a wide range of interpretive approaches.

Working Definition: Research Quality

In line with Kirk and Miller (1986), we define the quality of interpretive research as its capacity to generate "knowledge that is of interest on its own merits to those other than the friends and admirers of its creator" (p. 13). The knowledge produced is idiographic in nature, in that it emerges from the unique perspective of individuals or groups, but is transferrable to and meaningful for other contexts. This definition of quality through the worth (Lincoln & Guba, 1985) of a study's findings to others integrates notions of quality from what Borrego and Bernhard (2011) contrast as method-led and problem-led research traditions. More specifically, in their proposal, method-led research emphasizes the "proper use of methodology and quality of evidence," while problem-led research judges "quality on light shed on the problem under consideration" (p. 31). While we do not advocate a rigid, mechanistic application of methods as an indicator of quality, the contextual, reflective adoption of methodologies and their explicit documentation and communication are a core aspect of the process-focused quality framework presented here. The value of research is thus infused throughout the entire research process. The explicit inclusion of the research community as the "consumer" of research integrates into the framework the "focus on the quality of insights generated" that Borrego and Bernhard associate with problem-led approaches.

Following this line of argument, we agree with Flick that "quality cannot be reduced to formulating criteria and benchmarks for deciding about good and bad use of methods" (2006, p. 384). Quality, rather, is based on an overall judgment of knowledge claims that considers the trustworthiness of their production as well as the value of their application in generating understanding or effecting positive change in other social contexts. Our process-oriented quality framework makes the elements of this definition explicit, for example, in elements of procedural validation during the research design, processes of communicative validation with both participants and the research community, and attempts at pragmatic validation through the tentative transfer of research results.

The next section explores some epistemological and ontological assumptions relevant to the discussion of research quality through the example study. On this basis, the remainder of the article develops the quality framework drawing on both reflections from the example study and the intellectual traditions of interpretive research. More specifically, each aspect of quality, some of which were introduced above, is defined in theoretical terms, and the concepts are illustrated through examples drawn from our prior study, with the aim of facilitating further discussion and expansion of the framework and exploring its contextual adoption to other research settings.

Overview of the Example Study

The interpretive study that provides the context for our reflections on research quality is an exploratory investigation from a broad, holistic perspective of engineering students' competence formation (Walther, Kellam, et al., 2011). In this study, *accidental competencies*, or the unintended consequences of students' entire experience of completing an engineering degree, were conceptualized as a lens to investigate how students' overall competence formation emerges from the complex interplay of explicit instruction and a wide range of influences from the learning environment (Walther & Radcliffe, 2007b).

To broadly explore these unintended consequences, data was collected in focus groups based on critical incident techniques (Flanagan, 1954; McClelland, 1998; Walther, Kellam, Radcliffe, & Boonchai, 2009) with 58 students in their transition from university into professional practice. Additionally, nine students participated in a weekly self-recording of written critical incidents during the course of a semester-long industry placement program. The students were selected from a range of innovative placement programs (i.e., industry, co-op, and service learning programs) from institutions in Australia, Germany, Thailand, and the United States. This international selection ensured that a wide range of student experiences could be captured, and the focus on placement students meant that participants could recall in detail experiences from their education while also having had a significant exposure to engineering practice.

The focus group sessions were digitally recorded and transcribed for subsequent data analysis using the qualitative software NVivo7. The iterative analysis, based on a grounded theory approach and constant comparative methods, proceeded from descriptive topic codes for the educational influences and work situations that contributed to these learning processes (Walther, Kellam, et al., 2011) to interpretive clusters and subordinate categories that captured the competencies the students had developed. The competency codes included clusters for Flexibility, Interaction, Planning, Professional Realities, Self, Social Context, and Technical Expertise, with each cluster containing a set of categories of competencies. The Self cluster, for example, contained the category Perception of Professional Self (or identity formation) to capture learning processes that contribute to how the students conceptualized their own role as professional engineers. The theme used in the present article to illustrate all reflections on research quality was chosen from the Perception of Professional Self category, and captures how processes of identity formation are shaped in part through students' interactions with and perceptions of university instructors and industry supervisors.

Ontological and Epistemological Considerations in the Example Study

The prior study and the example theme serve a dual purpose in the present article. First, the following sections explore the ontological and epistemological considerations underlying the interpretive inquiry, not merely on a theoretical level but rather as they were manifested in a concrete research study undertaken in engineering education. Second, the latter part of the article draws on the same theme from the data to illustrate specific issues concerning research quality that led to the development of our quality framework. These illustrations throughout the article were drawn from the coding journal (Richards, 2005) of the primary researcher and from records of the research team's discussions. The coding journal, or log trail, was used to record developing understandings of patterns in the data and to deliberate issues arising during the iterative interpretation of the participant accounts. The meeting records similarly captured discussions of emerging codes or specific coding instances. The illustrations provided here are drawn from these records and are edited to provide focused accounts to explicate the specific points discussed.

Example Theme: Students' Development of Professional Self-Perceptions

To ensure that the following illustrations are set within a cohesive view of the results of the example study, they are based on one dominant theme that emerged from the analysis. This

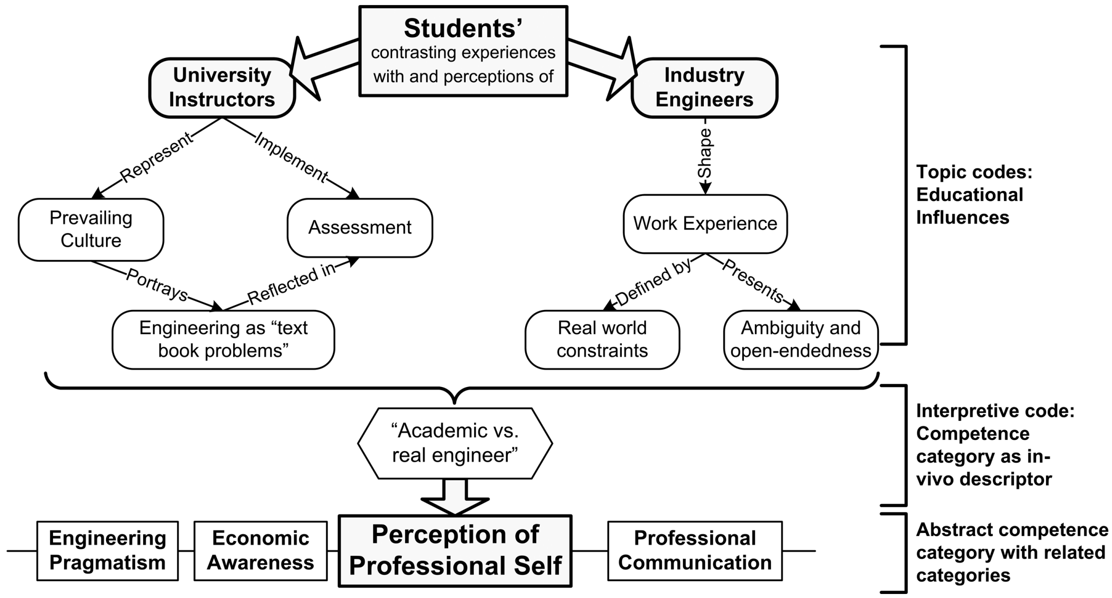

Figure 1 Partial influence model of how students developed a perception of their professional self from the contrasts they perceived between university instructors and engineers in industry. The process of interpretation through gradual abstraction is represented with examples for topic codes, the initial interpretive code with a descriptor taken from the participants' accounts, and the final abstract category of professional self-perception with related competence categories that emerged from similar analyses.

theme, concerned with engineering students' Perception of Professional Self, was conceptualized through the influences and competency outcomes as illustrated in Figure 1. Further details on the research method and results are introduced with the later illustrations as necessary.

In the focus groups, the students reported that instructors and industry engineers were role models who had a significant impact on the development of their professional self-perception. Figure 1 shows how the complex interplay of the influence of instructors and engineers with other educational factors shaped the students' "professional way of being" (Dall'Alba & Sandberg, 2006, p. 389).

When reflecting on their experiences, the students reported a range of critical incidents related to their interactions with or perception of engineering instructors and professional engineers during their time in industry and at university. One pattern concerned the contrast students perceived between the understanding of engineering work commonly portrayed in the university context and their experiences of engineering practice. The view of engineering work espoused in the university primarily stressed procedural aspects and the science content of engineering problems (Seely, 1999). Many participants reported that this view neglected the practicalities, complexities, and ambiguities of what Jonassen, Strobel, and Lee (2006) describe as "workplace problems."

Henry (all student names are pseudonyms), a final-year mechatronics student, for example, provided an account of a design project where the students' attempt to consider the economic aspects of a design did not agree with the instructor's perception of engineering work:

> Lecturers are never happy with the work-around solution, because that's not what they taught you. We've got these team projects to design and build a . . . circuit board and they give us a really tight budget. And so you can't afford all the fancy clips . . . so you use hot glue or basically anything so that you can loop around the budget. And then [the] lecturer . . . takes one look and says, "I don't like this . . . because it's not professional."

This "classroom problem" view (Jonassen et al., 2006) of professional engineering work held by some instructors was described by Henry as "all these little fiddly things he likes to stick to, this nice little protocol he likes. Everything's gotta fit into the box."

In contrast, students experienced some of their industry supervisors and peers as engaged in a more flexible and pragmatic approach to engineering that acknowledged the open-ended nature of engineering problems as well as practical constraints. In discussing the economic aspect in design work during his industry placement, Carl, a fourth-year mechanical engineering student, reported the opposite of a prescribed procedure or outcome: "I just have to make it work." Similarly, Henry commented that "The thing I got from the work: if it works and if you can afford it, go for it."

Consequently, the students' perception of their industry supervisors was shaped very differently. For example, Adam, another fourth-year mechanical engineering student, described an industry supervisor as "My boss, he is very good at what he does . . . he has all the experience . . . he can picture how things come together."

However, it is also important to point out that not all students related negative impressions of their instructors. For instance, in another part of the focus group Henry recounted: "Most of the lecturers in the mechanical engineering department have some ties into the real world. So they have something they can relate to."

This ambivalence in Henry's comments affirms that the data-gathering process was capable of capturing the intricacies that one would expect to see in a complex social context. Similarly, Acis, a fourth-year mechanical engineering student, remembered a particular instructor as "a really helpful person" and, at the same time, admitted to a prevalent student bias, referring to "a lot of stereotypes out there . . . of guys with comb-overs and poor social skills."

When forming perceptions of their own professional self, students most commonly aspired to the qualities they associated with "real engineers" and rejected attributes they considered typical of an "academic." In this process, some students also developed a number of qualities that related to other competence categories such as Economic Awareness, Engineering Pragmatism, and Professional Communication (see Figure 1). In this sense, the Perception of Professional Self category had an organizing and contextualizing effect on competencies in other clusters.

After providing this authentic, but necessarily limited, view of the example theme as it emerged from the data, the following paragraphs reflect on how some of the fundamental ontological and epistemological assumptions of interpretive research manifested in the example study to stimulate and shape our reflections on issues of research quality.

Ontological Considerations

The above-described theme concretely illustrates two main ontological assumptions of the interpretive tradition: (1) the socially constructed nature of the empirical reality and (2) the nondualistic position of the researcher in relation to this reality.

Socially constructed reality The first tenet assumes that reality is socially constructed (Hammersley, 1992; Huberman & Miles, 2002; Sandberg, 2005), or emerges from the multiple interactions of individuals in complex social settings (Davis & Sumara, 2006; Doll, Fleener, Trueit, & Julien, 2005; Mason, 2008). Thus, reality is neither assumed to be "out there" (Lincoln & Guba, 1985, p. 37) to be neutrally observed (materialism) nor solely "in the individual's head" (relativism). Rather, it extends beyond the individual, in that it is constituted through, and emerges from, the shared lived experience – the "Lebenswelt" (Husserl, 1936) of groups of individuals (Berger & Luckmann, 1966).

Illustration In our example the emergent or intersubjective reality of the phenomenon "role model" becomes evident when considering that, for the individual student, the influence of instructors and/or professional engineers is constituted by concrete psychological realities – for example, feelings of consternation or experiences of tensions between their own professional way of being and their perception of the workplace. The phenomenon of the instructor or professional engineer as a role model, however, only emerges from sustained and complex interactions between students, various instructors, and industry supervisors. More specifically, the influence of role models as the phenomenon under investigation consists of and, at the same time, exceeds the individual student's psychological realities and emerges on a higher level from complex social interactions.

Coming from an engineering background, the members of the research team experienced this aspect of interpretive ontology as a contrast to the implicit view of reality underlying more traditional forms of engineering science research. In a somewhat simplified way, this positivist view of traditional engineering and science assumes a transcendent, materialistic reality that can be known independent of context and time. By contrast, the research "object" of this study was an emergent, nonmaterial, and contextual phenomenon that was, however, very real and impactful in the students' experiences. This observation suggests, as Hammersley (1992) states, that in the context of the interpretive inquiry, "there are phenomena independent of our claims about them which those claims may represent more or less accurately" (p. 51). Acceptance of socially constructed phenomena that exist regardless of our efforts to describe them, in turn, implies that quality judgments are necessary and possible in the context of interpretive research. It also follows that engineering science models for making such judgments are at best inadequate and at worst misleading when applied to the study of emergent, nonmaterial, and contextual phenomena.

The various traditions of interpretive research suggest a range of strategies and conceptions for assessing quality. In this article, quality strategies pertaining to socially constructed reality as the "object" of research are synthesized through the notion of "communicative validation," as presented in the quality framework below.

Nondualistic ontology The previous section described how the phenomenon of role models was socially constructed through the students' interactions with instructors and industry supervisors. In collecting and analyzing the data, it became apparent that accounts of these experiences were similarly co-constructed between the researcher and the participants. Lincoln and Guba (1985) point out that this process of co-construction means that "the enquirer and the 'object' of inquiry interact to influence one another; knower and known are inseparable" (p. 37). In the example project, we realized that no matter how carefully the research is designed and conducted, the researcher is always connected to and, to some degree, influences and is influenced by the social situation under investigation; that is, "the object of science is also the subject of science" (Apel, 1972, p. 3).

Illustration To exemplify this point, this illustration builds on the example used above. When discussing the students' experiences concerning university instructors in the focus group, I (first-person account in this and subsequent illustrations refers to the

> experience of the first author in conducting the research) found that my personal background inescapably affected which information the students shared with me and how they presented it. More specifically, I observed that the students were more likely to regard me as a fellow student due to similar age and the shared experience of an engineering degree and because I was not involved in the teaching or assessment of any of their courses. Thus I found that the students were more likely to share unfiltered, critical accounts about their experiences with instructors with me than, for example, someone they were likely to perceive as an instructor. On the one hand, this special rapport allowed me unique access to this particular aspect of the students' social reality, but, at the same time, it was also a potential reason why this aspect of their relationship to instructors was particularly prominent in the data I collected. In this way, my personal impact on the data-gathering situation shaped the results of the study.

While it is a familiar assumption in engineering science that the act of measuring can affect the properties of the measured object, the example above illustrates how inextricably connected the researcher is to the social context under investigation. This nondualistic assumption that researcher and respondents are linked as parts of the same lived experience means that a specific, contextual version of the social reality is constructed in the data-gathering situation. In our example, the process of eliciting student accounts was potentially biased by the experiences of the focus group facilitator, for example, by his tendency to focus follow-up questions on aspects of the students' experience that resonated with his own. This issue of bias also hints at aspects of subjectivity in the data analysis, as discussed in the next section. The respondents' contributions were equally shaped by their perception of both the data-gathering situation and the researcher, as discussed above.

For the research results, these dynamics meant that, while multiple alternative perspectives on the data are possible, one particular version of the social reality was represented in the findings. More specifically, the influence of role models emerged as one facet of students' reality from the specific interactions and dynamics of the data-gathering situation. That there are possible alternative versions and other facets does not, however, detract from the value of this finding as a way of understanding a particular aspect of engineering education. In order to serve this purpose, though, the above-described dynamics need to be acknowledged in the research process and communicated as part of the findings. In the quality framework developed below, this need for reflexivity and disclosure is reflected in the process view that spans the entire research process.

Epistemological Considerations

From the emergent, intersubjective nature of social reality as the "object" of research, a number of considerations about the ways in which we can know something about this reality (epistemology) arise. By reflecting on our own processes of sense making, we identified a number of examples that illustrate how (1) subjective interpretation was the primary way of generating knowledge claims and (2) how knowledge was socially constructed throughout the research process.

Subjective interpretation to generate knowledge In the previous section, we discussed how their version of reality that students shared in the focus groups emerged from the dynamics of the data-gathering situation. In interpreting these accounts, we considered that there were, again, many possible ways of making sense of the rich tapestry of the students' experiences. Specifically, the representation of one particular interpretation was inevitably informed by the primary researcher's background, own experiences, and biases.

> **Illustration** In examining students' accounts relating to their interactions with instructors and professional engineers, my view as a "former participant" who had experienced some of the same tensions, as well as my role as an engineering educator who aspires to effect change in students' educational experiences, predisposed me to recognizing this pattern of the ambivalent effect of role models that was present in the data. This does not mean that I arbitrarily selected one particular version of events from the data or misrepresented participants' shared perspectives. Rather, the interpretation emerged purposefully from the combination of the data and my interpretive view. More specifically, while my bias informed the identification and framing of the pattern in the data, the interpretation was, at the same time, grounded in the data and deliberately developed through processes of constant comparison.

This example thus illustrates that the lead author's interpretive view, with its preconceptions and biases, combined in a purposeful way with processes of interpretation that were grounded in the data to yield a meaningful representation of a phenomenon that was a significant part of the participants' experiences.

This illustration shows that, as Kirk and Miller (1986) state, the social system under investigation does not "determine absolutely the one and only correct view that can be taken of it" (p. 14), nor does it "tolerate all understandings of it equally" (p. 11). In the development of the quality framework described below, we synthesize strategies that purposefully legitimize the representation of one particular interpretation under the notion of procedural validation.

Social construction of knowledge claims Following from the above-described process of identifying a meaningful interpretation of the social reality under investigation, the next challenge was to adequately represent this interpretation, that is, to "call things by the right names" (Kirk & Miller, 1986, p. 23). In our study, we experienced this social construction of knowledge claims within the meaning conventions of the research community as a fluid continuation of the social constructions that emerged in the data-gathering situation.

> **Illustration** In the data-gathering situation, the students spoke of their individual experiences with instructors and industry supervisors and of other educational influences. In this discussion, a shared, multifaceted view of the phenomenon emerged between the students. This understanding was constituted by their multiple perspectives but was, at this point, of a tacit nature, i.e., everyone knew what was being talked about and contributed related stories but the students did not explicitly frame this as the influence of "role models." In the initial data analysis, this shared understanding emerged across several transcripts and was at this stage captured in a preliminary node with the in vivo description "academics versus real engineers." This first interpretation was socially constructed, in that it emerged from the students' shared understanding in several focus groups. In terms of useful knowledge, though, this interpretation did not extend far beyond the context of the focus groups.
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> In working "up from the data" (Richards, 2005, p. 73), an instructor's influence can be described using the term role model. This name for the emerging coding category was one of several choices and was, as such, not directly "imposed by the structure of empirical reality" (Kirk & Miller, 1986, p. 15). More importantly, my choice of this term on the basis of my interpretive judgment also applied a range of preexisting conceptions and frameworks from the literature to this coding category. In a historical perspective, the notion of *role model* was proposed as a specific sociological concept by

> Merton, Reader, and Kendall (1957) in their study of medical education before the term became part of everyday language. Merton and colleagues defined a student's role model as "a figure in the profession, a personality or one only known by repute, as a model . . . with which to compare their performance" (p. 137). This meaning convention shows that the naming of the coding category in our analysis did not occur in an empty space, but was socially constructed, in that the term chosen is associated with specific meaning within a research community. Interestingly, in his later work, Merton (1994) describes how "that once well-defined sociological term [has] now become blurred if not vacuous by frequent and indiscriminate use" (p. 374).

This illustration shows the multiple, interlocking acts of social construction that span the entire process, from data gathering to communicating the finding to the research community. In the quality framework presented here, this characteristic of interpretive research is reflected in the process view that spans this entire range. Existing strategies to guide and make this process of social construction explicit are synthesized as the notion of communicative validation described below.

Implications for Research Practice: Development of a Quality Framework

These reflections on the challenges of investigating a socially constructed reality from an interpretive, nondualistic stance led to the question of how the notion of research quality that was defined at the outset of this article could be achieved in our particular investigation.

In addressing these challenges, we developed a process-oriented framework that synthesized and contextually systematized existing concepts and strategies concerning research quality. This framework was thus set in and emerged from this particular inquiry. By its nature, it is not limited to a particular research tradition and is offered here as a parsimonious framework that can be transferred to or stimulate discussion in a broad range of research approaches currently used in engineering education research.

Terminology of Research Quality for a Diverse Research Community

A key challenge in developing such a framework for a research community that represents a wide range of understandings of qualitative research – both in terms of methodological traditions and in terms of levels of experience (Borrego, 2007a) – is choosing appropriate terms to describe fundamental concepts of research quality. From the range of possible available terms in the literature, we adopted and reinterpreted *validation* and *reliability* for the following reasons.

These terms build on our own experiences from an engineering background (precision and accuracy) and thus may offer a useful bridging paradigm for engineering education researchers with similar disciplinary backgrounds. Moreover, these terms express fundamental notions of quality that we contend are, on a very basic level, independent of the research paradigm. Thus, our reinterpretation and use in developing this framework does not imply a positivist stance.

Validity (accuracy) as the "agreement of the results of a measurement with the true value of the measured quantity" (Sirohi & Radha Krishna, 1983, p. 39) can be redefined as the extent to which the research findings appropriately reflect properties of the social setting investigated. This interpretation of validity acknowledges the considerations of multiple realities and multiple subjective versions, but frames the notion of validity as the question of "whether the researcher sees what they think they see" (Flick, 2006, p. 371) and reports this in accordance with the meaning conventions of the research community.

Similarly, reliability (precision) as the "the repeatability of a measuring process, i.e., the closeness with which the measurements of the same physical quantity agree with one another" (Sirohi & Radha Krishna, 1983, p. 40), can be expanded to acknowledge the ontological and epistemological considerations of interpretive research. More specifically, because the complex nature of the social systems investigated precludes exact replication of any form of observation, reliability can, at a very fundamental level, be understood as the attempt to mitigate the effect of random influences on the research process. In other words, if we are reasonably certain that we "see what [we] think [we] see" (Flick, 2006, p. 371), we should try to do so as consistently and independently as possible from the "accidental circumstances of the research" (Kirk & Miller, 1986, p. 20). This definition also highlights that reliability can only be a "necessary but insufficient condition for validity" (Cohen et al., 2000, p. 105). Other authors refer to eliminating random influences on the research process as dependability (Flick, 2006; Huberman & Miles, 2002; Leydens et al., 2004).

Instead of reinterpreting the traditional criteria outlined above, alternative criteria, such as trustworthiness or confirmability (Lincoln & Guba, 1985), offer an inherent emphasis on the assumptions underlying interpretive research. However, we argue that this terminology does not have the same ability to bridge understandings within the engineering education community and that these concepts have not been translated into specific and systematic ways to foster research quality. Flick (2006) contends that they "remain on the programmatic level" (p. 376) and have not "yet given a really satisfactory answer to the problem of grounding qualitative research" (p. 380). In addition, the reinterpretation of traditional criteria introduced above is, in principle, congruent to alternative criteria, and some authors suggest that a relatively clear mapping can be achieved between different types of validity and reliability and the concepts of confirmability, transferability, credibility, and dependability (Miles & Huberman, 1994). While in this project we did not choose to conceptualize quality through alternative criteria, these criteria provided a valuable perspective, in that they offered a holistic view of the research process that shifts the attention from solely assessing the quality of research outcomes to considering the quality of the overall research process.

In summary, we chose the term *validation* to better highlight the process character of the framework and the term *process reliability* as an accessible way of conceptualizing research quality without assuming the positivist stance of the intellectual traditions from which these terms originated.

Beyond Standards of Quality: An Engineering Process Metaphor for Research Quality

When we used validation and reliability in discussing research quality in the example study, it became apparent that their role in judging research quality differs significantly from their use in the positivist paradigm. Whereas positivism derives quantifiable standards of validity and reliability, the nature of research problems in the interpretive inquiry precludes defining such measures. Flick (2006) confirms that "quality in qualitative research cannot be reduced to formulating . . . benchmarks for deciding about good and bad use of methods" (p. 384).

Illustration In the example study, the act of meaning making consisted of iterative and inherently subjective processes of piecing together subtle nuances in students' stories, evaluating conflicting accounts, and integrating implicit references to underlying

> dynamics (which were not necessarily obvious to the participants themselves) to arrive at a rich understanding of the influences at play in students' formation of their professional identities. As the interpretation progressed, role model was chosen as the appropriate language both to capture one significant aspect of this image that emerged in the researchers' minds and to resonate with, and be potentially useful for, other educators. From this description, it is obvious that the research finding cannot be judged in its quality by using an a posteriori measure applied to the result only (in the way one would apply the measure of statistical significance to the results of a survey study).

To move beyond the limitations of criteria and associated standards, this article proposes to embed reinterpreted notions of validation and reliability into a process-oriented model based on the engineering metaphor of quality management, a concept that transfers the responsibility for quality from an assessment of the final product to a process of continuous improvement that involves all stakeholders throughout the production process (Cottman, 1993; Zairi, 1993).

Transferring the concept of quality management to interpretive research quality in engineering education thus allowed us to conceptualize a procedural, continuous, and holistic approach to quality that shifts the attention from defining standards of rigor applied to the research results to viewing, demonstrating, and assessing research quality throughout the entire research process. In a general discussion of qualitative research, Flick (2006) hints at such a process-oriented approach to quality control in stating that "the issue of quality in qualitative research is located on the level of research planning, from indication of research designs and methods, to quality management on the level of process evaluation" (p. 384). The model presented here thus synthesizes existing concepts of research quality in a coherent way and also provides a useful bridging paradigm for engineering education researchers with traditional engineering backgrounds.

Drawing on the language of quality management, the process model presented in Figure 2 defines the research process as the two major stages of *making the data* and *handling the data*. This view of the research process is not intended to imply a sharp distinction or to neglect the iterative fluidity that characterizes interpretive inquiries. Rather, we define the process dimension of the model in very generic terms to accommodate the methodological diversity of interpretive research in the engineering education community. The stage of making the data emphasizes the "internal customers" in the process, such as the research participants and fellow researchers. This stage includes the steps of research design and data gathering, which focus on co-constructing an understanding of the participants' "experience-near constructs" (Geertz, 1974, p. 28) between the researchers and the researched. Handling the data, as the second stage, considers the "external customers," or the consumers of the research. This stage comprises the interpretation and generation of knowledge claims, as well as the representation, dissemination, and application of theory; these processes establish and communicate the "experience-distant constructs" (p. 28) within the research team and the research community to represent the research findings.

In this process-oriented model, the researcher can locate strategies that contribute to overall validation and reliability within the research process and explore their specific function in a particular stage of the inquiry (Figure 2 gives examples of applicable strategies; Table 1 presents a more detailed view). The strategies were drawn from suggestions in the literature, and the model serves to explicate their contribution to research quality appropriate

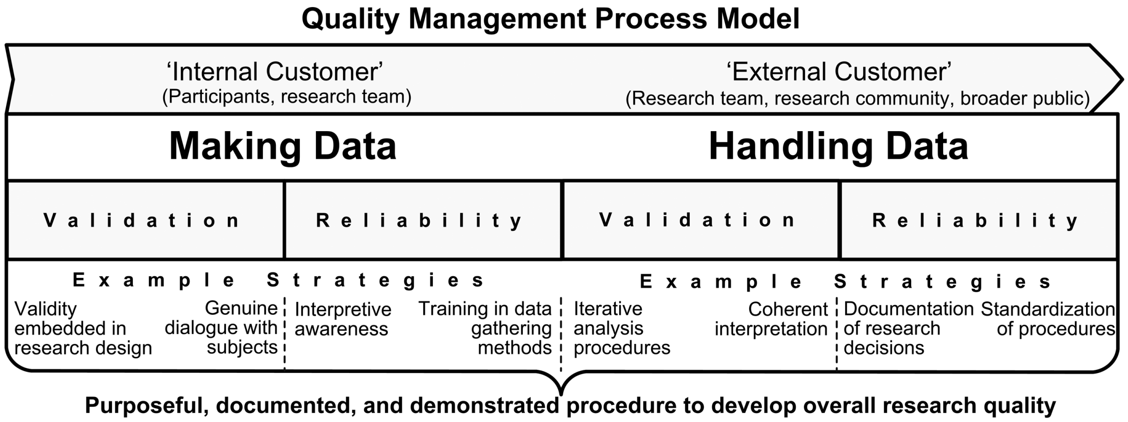

Figure 2 Quality management model of the research process with stages of the research and example quality strategies.

to the setting, purpose, and approach of the particular inquiry. The discussion of quality strategies in this article is not exhaustive but, rather, represents a selection suitable for the research design of the example study.

Typology of Validation Constructs and Process Reliability

The above process model constitutes the first dimension of the overall quality framework proposed here. In addition to this process component that locates quality strategies throughout all stages of the research, the typology of quality strategies developed below (see Table 1) provides the second explanatory dimension to support their systematic application. More specifically, in the example study the process model allowed the researchers to determine when a specific quality strategy was applicable, and the typology fostered a critical exploration of its specific contribution to overall research quality in this particular study.

Previously, the core notion of validity was summarized in the question "Does the researcher see what they think they see?" (Flick, 2006, p. 371). For making the data, which is focused on the process of observation, validation thus relates to the question "what . . . the relations [would] look like if they were not issues of empirical research" (Flick, 2006, p. 371). Handling the data consists of the interpretive process and the development of theory. In this research stage, validation is concerned with whether the interpretations appropriately reflect the reality observed, that is, whether "the researcher's version [is] grounded in the versions of the field" (Flick, 2006, p. 371). With respect to deriving and presenting theory, this article has argued that the social reality itself does not "determine absolutely the one and only correct view that can be taken of it" (Kirk & Miller, 1986, p. 14). Thus, validation in handling the data also includes "calling things by the right names" (Kirk & Miller, p. 23) within the meaning conventions of the research community.

To operationalize the above broad definition, we propose the following processes of validation and reliability as fundamental ways to contribute to and demonstrate the overall quality of interpretive research. This proposal is not intended as a comprehensive coverage of all possible aspects of quality management; rather, we present the considerations that emerged as relevant in the example study to illustrate the idea of fundamental types of validation that are not linked to a particular research tradition or specific practices.

Table 1 Typology of Quality Strategies

		Making the Data		Handling the Data	
	Description	**Focus**	**Example Strategies**	**Focus**	**Example Strategies**
Validation	How can we improve the research findings' capacity to appropriately capture and represent aspects of the social reality observed?	Do we get to see what we think we see?		Is the researcher's version grounded in the versions of the participants? Do we call things by the right names?	
Theoretical Validation	Do the concepts and relationships of the theory appropriately correspond to the social reality under investigation?	The research process needs to be able to capture the full extent of the social reality studied.	• Purposive Sampling • Emergent research design	Interpretations need to reflect the coherence and complexity of the social reality under investigation.	• Analytic Induction • Negative Case Analysis
Procedural Validation	Which features of the research design improve the fit between reality and the theory generated?	Strategies need to be implemented in the research design to mitigate threats to contextual validation.	• Critical Incident Techniques • Triangulation	Processes need to be implemented to mitigate risks of mis-constructing the participants' reality in the researcher's interpretations.	• Constant Comparative Method • Interpretive Awareness
Communicative Validation	Is the knowledge socially constructed within the relevant communication community?	The data gathering needs to capture the respondents' inter-subjective reality.	• Focus groups to establish genuine dialogue • Development of shared narratives • Exploring participants' contrasting accounts • Member Checks	The researcher's abstract inter-pretations need to be grounded in the accounts of the participants.	• In-vivo coding of first interpretations • Ongoing engagement with the data
				The knowledge produced needs to be represented in accordance with the meaning conventions of the research community.	• Peer Debriefing • Relating theory to literature • Exposing knowledge claims to the discourse in the research community
Pragmatic Validation	Do the concepts and knowledge claims withstand exposure to the reality investigated?	The concepts underlying the research design need to be compatible with reality in the field.	• Diversity of respondents • Prolonged exposure to practice	The knowledge produced needs to be meaningful in the social context under investigation.	• Applicability Studies • Explanatory power of results
Process Reliability	How can the research process be made as independent as possible from random influences?	The data needs to be collected and recorded in a dependable way.	• Documented focus group protocol • Checking of transcripts • Training in research procedure	Procedures for generating and representing knowledge need to be established and documented.	• Standardized notes and memos • Procedures of cross-checking • Separating descriptive and interpretive coding

Theoretical validation focuses on the fit between the social reality under investigation and the theory produced.

Procedural validation suggests incorporating features into the research design to improve this fit.

Communicative validation accounts for co-construction of knowledge in the social context under investigation as well as within the research community.

Pragmatic validation examines the extent to which theories and concepts are compatible with the empirical reality.

Process reliability provides the necessary conditions for developing overall validation through strategies aimed at making the research process as independent from random influences as possible.

The following sections detail these concepts by, first, defining each in accordance with the ontological and epistemological considerations outlined above and, second, exploring its meaning for the two stages of *making the data* and *handling the data*.

Theoretical Validation

Theoretical validation is the most fundamental aspect of managing quality in interpretive research. Hence, the other types of validation discussed in later sections can be understood as contributing to theoretical validation. Theoretical validation implies a continuous focus on the question of whether the theories or the knowledge produced appropriately correspond to the empirical reality observed. This proposition also highlights that, while the notion of theoretical validation focuses on the generation of abstract knowledge, the consideration of this aspect needs to span the entire research process.

Making the data thus needs to lay the foundations to make the generation of theory and its contextual validation, in principle, possible. On a fundamental level, the research process thus needs to be able to capture the full extent of the social reality that is of interest. This need arises from the emergent nature of social reality, as discussed earlier. The "object" of research is the intersubjective reality that "becomes accessible [only] across the different perspectives" (Hammersley, 1992, p. 50) that individuals contribute in the form of subjective experiences of their social context.

In order to capture these multiple perspectives, several authors have suggested strategies such as "purposive sampling" (Lincoln & Guba, 1985, p. 40) or "theoretical sampling" (Flick, 2007; Glaser & Strauss, 1967) that increase "the likelihood that the full array of multiple realities will be uncovered" (Lincoln & Guba, 1985, p. 40). This approach to sampling means selecting a diverse range of participants concurrently to and in accordance with the emergence of theory. The selection is thus based on informational considerations rather than on prior random or representative sampling. In the example study, students were selected from different universities in different countries, with a focus on innovative placement programs, in order to capture the full breadth of students' possible experiences of engineering practice. The inclusion of students from a service learning program, for example, contributed an interesting perspective on social aspects of engineering work, whereas this aspect was not equally manifest with students from traditional industry placement programs. Deriving interpretations across these perspectives ensured that a full range of students' experiences were captured and formed the basis for the interpretive generation of theory. In a similar way, strategies such as an “emergent design” (Lincoln & Guba, 1985, p. 41) of the research methodology or conducting research in an authentic or “natural setting” (p. 38) ensure sufficient flexibility and openness to allow for the unknown to be discovered.

In **handling the data,** theoretical validation pertains to processes which “go beyond concrete description and interpretation and explicitly address the theoretical constructions that the researcher develops . . . during the study” (Maxwell, 1992, p. 291). These theoretical constructions are composed of the *concepts* as building blocks of theory and the *relationships* that are assumed to exist between the concepts. The former are addressed in the notion of construct validity, while the latter are commonly associated with internal validity (Kirk & Miller, 1986; Maxwell, 1992).

Theoretical validation with respect to the concepts of theory concerns “the legitimacy of the application of a given concept to established facts” (Maxwell, 1992, p. 292). Once an “agreement can be reached about what the facts are” (Maxwell, 1992, p. 292), a process of social construction itself, theoretical validation refers to representation of theory within the socially constructed meaning conventions of the research community. This aspect is discussed in more detail when examining processes of communicative validation in a later section. The theoretical validation of relationships is not focused on existing meaning conventions but rather allows a view of the complex nature of the interactions of the elements of the social system under investigation. In this regard, theoretical validation can be achieved through the systematic exploration of the intricacies inherent in qualitative data, with specific attention paid to coherence and complexity.

Social systems are not chaotic but show self-organization and coherence (Cilliers, 1998; Mason, 2008; Sawyer, 2005). This coherence needs to be reflected in the researcher’s interpretation; that is, the theory derived needs to “make sense” (Charmaz, 2006, p. 183) or “seem plausible” (Huberman & Miles, 2002, p. 271). Other authors have conceptualized this as resonance (Charmaz, 2006; Lincoln & Guba, 1985) or authenticity (Flick, 2006). The demonstration of coherence of interpretation across the multiple perspectives captured in the data thus supports claims for theoretical validation.

Coherence, however, does not mean uniformity, and claims to theoretical validation can be supported by combining the demonstration of coherence in interpretation with the exploration of the complexity inherent in the data. The emergent nature of social reality suggests “intricate relationships between the components” (Cilliers, 1998, p. 2). Thus, the exploration of complexities focusing on the demonstrated analysis of contradictions or deviant cases supports claims to validation. One would simply expect to find these tensions and contradictions in rich data; in fact, if the data did not contain these complexities, they could be suspect in the sense of “quixotic reliability” (Kirk & Miller, 1986).

This concept of theoretical validation through the exploration of coherence and complexity is reflected in the formulation of systematic ways to inductively generate theory from the examination of (relatively few) individual cases. Analytic induction (Znaniecki, 1934), for example, describes a procedure whereby preliminary theory in the form of hypotheses, patterns, or models is formulated from examining a case. The theory is reformulated and adapted in the subsequent exploration of other cases in the data with particular consideration of “the exception, the case, which is deviant to the hypothesis” (Buehler-Niederberger, 1985, p. 476). Lincoln and Guba (1985) formalize this analysis of the tensions within the data as “negative case analysis” (p. 206).

The following illustrates several aspects of theoretical validation and their connection to other concepts of validation using data from the example study.

Illustration Validation of the concept of role model in relation to its use in the literature was discussed above. This illustration focuses on strategies for theoretically validating relationships between concepts in the data (internal validity) by examining the diversity of participants' accounts with a particular focus on coherence and complexity.

Interpretation of the focus group transcripts led to the conclusion that students' formation of their professional self-perception was partly shaped by the influence of instructors as role models. However, individual incidents of competency formation in the transcripts were very diverse and depended on a variety of influencing factors. For example, in one recurring pattern, students reported their instructors' influence as a sort of antipole to their perception of industry supervisors; this pattern suggests that neither instructors nor industry supervisors were role models simply by themselves; only the contrast that students experienced between specific instructors and specific engineers prompted reflection on their own role as professional engineers.

An example of a "deviant case" is a student who reported perceiving a particular instructor as a role model that was in agreement with his own perception of a professional engineer. More specifically, Denny, a graduate mechanical engineer, reported, "During my work, I sometimes remember certain lecturers from university. Particularly, the academic who taught [name of course] was a good example how to professionally present engineering content."

This contrast to the pattern observed above, though, does not mean that the instructors' influence as negative role models does not reflect the students' reality. Rather, the deviant case might need to be analyzed in a wider context to achieve coherence of interpretation. In this case, the student had completed his education at a German university where most instructors have significant and ongoing industry experience. Consequently, this student's perception of instructors differed from that of students in other countries. We do not suggest that all tensions in the data need to be explained away. Rather, this case provides an example that the exploration of tensions can sometimes yield a deeper understanding of the social reality observed.

This example also demonstrates in another way how negative case analysis can support claims to overall validation. An earlier illustration discussed the possible influence of my role as a researcher on the students' responses. In some of the transcripts, passages were identified where the students uniformly portrayed negative perceptions of instructors in general terms without providing specific incidents or details. From the perspective of theoretical validation, this becomes problematic, since it is not clear whether these contributions actually reflect the students' reality or were born from the dynamic of the data-gathering situation. The negative case analysis presented above can mitigate this threat to validity. More specifically, despite the problematic impact of the good rapport between researcher and respondents, the deviant case shows that the data-gathering situation was, in principle, open enough for this perspective to be captured (see also the discussion of Henry's ambivalent experiences in the earlier description of the example theme). Yet, this potential threat to quality also necessitates strategies for dealing with dubious accounts in the subsequent interpretation of the data. The discussion of procedural validation in the next section further explores this question.

In summary, this example illustrates how the demonstration of diversity of the data, the coherent interpretation of contrasting patterns, and the explicit analysis of deviant cases can support the theoretical validation of research findings.

Procedural Validation

Procedural validation summarizes elements and procedures that can be incorporated into the research design to mitigate threats to overall validation. The process-oriented approach we propose includes a strong focus on both defining and following such procedures and on their explicit demonstration when presenting the results. The literature offers diverse strategies that can be implemented in the research design (Fielding & Fielding, 1986). These strategies of procedural validation are particularly specific to the individual research setting and approach. To illustrate the underlying principles of procedural validation, the following discussion is limited to selected strategies that were significant to the example study.

In **making the data**, procedural validation focuses on implementing validation strategies in the research design. One of the most significant threats to the validity of interpretive research is the possibility that informants "consciously or unconsciously construct a specific, that is, biased version of their experiences that does not [correspond] or does correspond with their views in a limited way" (Flick, 2007, p. 16).

In the context of research concerning competence or the performance of individuals in professional practice, accounts are typically influenced by the respondents' "espoused beliefs" (Argyris & Schoen, 1974), inaccurate self-assessments (Boyatzis, 1982; McClelland, 1998; Spencer & Spencer, 1993), or what Maxwell (2005) calls "self-report bias" (p. 112). To mitigate this threat in the example study, the data-gathering procedure was based on critical incident techniques (Flanagan, 1954; McClelland, 1973, 1998). The focus of the group discussions of actual incidents from their experiences was intended to minimize students' contribution of general opinions or beliefs. This strategy made it more likely to elicit the students' "theories in action" (Argyris & Schoen, 1974), which are more reflective of their behavior in the respective social context than students' self-assessment of their learning. In spite of the purposeful use of this research strategy, the critical incident method did not completely prevent biased responses; that is, some students still expressed general opinions and beliefs. To mitigate the influence of these questionable contributions on the research findings, we judged the validity of these accounts during the data analysis on the basis of whether they were supported by a critical incident account.

Triangulation has been suggested as another strategy to contribute to procedural validation (Fielding & Fielding, 1986; Maxwell, 2005). In the example study, we employed triangulation of "geographically disparate data" (Gibbs, 2007, p. 94), as well as a self-recording procedure to complement the data from the focus groups. The former contributed to the validation of the results, in that the phenomenon of accidental competency formation was part of the social reality of a culturally diverse range of individuals. Triangulation with self-recording data indicated that observation of the phenomenon in the focus groups was not a mere artifact of, for example, the dynamic of the data-gathering situation.

In **handling the data**, procedural validation entails systematic and documented processes of analysis and interpretation that mitigate the risk of misconstructing participants' shared lived reality in the interpretation. In the introduction to the example study, the data analysis was described as an iterative procedure of rereading the transcripts and different ways of cross-checking coding categories.

Glaser and Strauss (1967) and Glaser (1969) formalize this process as the "constant comparative method" by which "researchers engage in detailed analytic processes that require repeated confirmations of potential explanatory patterns discovered in the data" (Hatch, 2002, p. 26). The iterations of the constant comparative method include "(1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) delimitating the theory, and (4) writing the theory" (Glaser & Strauss, 1967, p. 105). This systematic circularity ensures that interpretations are grounded in the respondents' perspectives and reflect the complexities of their social reality. The explicit documentation of this process links this aspect of procedural validation to process reliability as discussed below.

Another element of procedural validation that spans the entire research process concerns the role, influence, and possible bias of the researcher. In **making the data,** strategies to account for bias include withholding, or "bracketing," prior interpretations or suspending abstract analysis when entering the field (Ashworth, 1999; Sandberg, 2005). These strategies allow "the life-world of the participants in the research to emerge in clarity" (Ashworth, 1999, p. 708). In the example study, mitigating the researchers' influence in facilitating the focus groups was, for example, achieved through a protocol that focused on eliciting specific events and avoided follow-up questions aimed at possible abstract interpretations of a student's account. Nonetheless, the discussion of the nondualist ontology of interpretive research demonstrated that neutral observation is, in principle, impossible. This insight suggests that possible influences from the researcher also need to be considered when **handling the data**. In this stage, explicit reflection on the researcher's bias or impact on the data develops "interpretive awareness" (Sandberg, 2005). The crucial function of this awareness in judging the validity of data was demonstrated in the illustrations above when discussing the impact that the researcher's rapport with the respondents had on the type and range of their contributions.

Drawing on the examples discussed above, we define the core meaning of procedural validation as incorporating structural features into the research design (e.g., critical incident techniques, iterative data analysis, interpretive awareness, etc.) that make it, in principle, possible to capture an adequate view of the social reality observed and derive knowledge claims that correspond to it.

Communicative Validation

The key function of communicative validation is to establish a "community of interpretation" (Apel, 1972) with both the internal and external customers of the research (see Figure 2). Considering the emergent and intersubjective nature of social reality, the generation of knowledge depends on the communication of multiple perspectives. In other words, since knowledge does not rest on, as Apel points out, "an exchange between man and the world of objects, but . . . an exchange between men in a communication-community" (p. 27), validation occurs in the social construction of knowledge (Mischler, 1990). This construction of knowledge takes place both in the data-gathering situation and in the representation of theory within the research community. Communicative validation thus spans the entire research process and in each stage "depends on a consensus within the relevant community" (Maxwell, 1992, p. 291).

In **making the data**, "the relevant consensus rests to a substantial extent in the community studied" (Maxwell, 1992, p. 209). Depending on the research context, communicative validation in this stage of the inquiry can take the form of a tacit agreement on the "experience-near" (Geertz, 1974) concepts between the respondents or a formal "member check" (Lincoln & Guba, 1985, p. 314) of the researcher's abstract interpretations.

On a tacit level, "subject agreement" (Flick, 2006, p. 373) can be achieved by establishing a "genuine dialogue" (Sandberg, 2005, p. 373) to access the respondents' multiple perspectives of their shared social reality. This genuine dialogue must be based on the participants' knowledge of the purpose and concepts of the research (Apel, 1972; Sandberg, 2005) and can be supported, for example, by careful moderating techniques in focus groups or interviews (Walther et al., 2009; Walther & Radcliffe, 2007a). The following example illustrates what such a genuine dialogue might look like in a data-gathering situation and how it can be actively fostered by the researcher.

> **Illustration** In the example study, the focus group procedure emphasized students' accounts of concrete situations and sought to avoid abstractions on the respondents' part. Yet, respondents often contributed a series of accounts related to a particular competence concept in the form of shared narratives (Clandinin & Connelly, 1989) without having to define the abstract concept. This dynamic meant that the students explored a shared facet of their lived experience based on an at least tacit agreement about the experience-near concepts that connected their accounts. Such a genuine dialogue can be supported by the researcher in, for example, initiating and guiding meaningful discussions about contrasting accounts of respondents.

For the purpose of establishing communicative validity with the respondents beyond the data-gathering situation, the literature offers various strategies for respondent validation (Maxwell, 2005; Miles & Huberman, 1994). Examples are member checks, which are based on the possibility to gain explicit agreement from the respondents concerning the data collected. In a basic form, member checks can include the confirmation of the accuracy of the data recording (see also Process Reliability below). Researchers can also present respondents with abstract interpretations and seek their confirmation. However, the very nature of the social construction of knowledge from multiple perspectives makes this form of validation problematic when "the research systematically goes beyond the subject's viewpoint, for example in interpretations . . . which derive from the distinctiveness of various subjective viewpoints" (Flick, 2006, p. 375).

In **handling the data**, communicative validation is concerned with "consensus . . . in the research community about the categories used in description" (Maxwell, 1992, p. 290). In this process of deriving the experience-distant concepts from the data through abstraction, the researcher needs to ensure, first, the grounding of the abstractions in the respondents' accounts and, second, the appropriateness of the terms used to describe theory with respect to the research community's meaning conventions.

In the first steps of interpretation, the researcher's "accounts of meaning must be based initially on the conceptual framework of the people whose meaning is in question" (Maxwell, 1992, p. 289). In a way, this continues the communication community established in the data-gathering situation through a systematic and sustained engagement with the respondents' accounts. As a specific example strategy, the selection of in vivo descriptions when forming the initial categories was mentioned above. The category to capture the formation of the students' professional self-perception, for example, was (borrowing from the students' own words) initially termed "academics versus real engineers." The use of this experience-near category name in the first loops of iterative interpretation provided sufficient flexibility for the development of the category and, at the same time, ensured that the subsequent abstract interpretations were "based on the construction [of knowledge] in the field" (Flick, 2006, p. 380).

In the increasingly abstract interpretation and the subsequent formulation of theory, communicative validation refers to "calling things by the right names" (Kirk & Miller, 1986). Because knowledge is also socially constructed within the research community, this aspect is not merely a matter of definitions. Rather, communicative validation entails the negotiation of appropriate representations of theory on several levels within the research community: "validity claims are tested through the ongoing discourse among researchers" (Mischler, 1990, p. 415). One immediate objective when interpreting data is thus the generation of theory through engagement with and reference to the literature. Within a team of researchers or an institution, systematic checks in the form of "peer debriefing" (Lincoln & Guba, 1985, p. 308) can be established. On the level of an international community of scholars, publication of results becomes part of the process of validation. Kirk and Miller (1986) describe this process as "a commitment to integrating new findings into the cumulative body of collective knowledge and confronting ideas with data as well as argument" (p. 79). In the same way that theory draws on existing meaning conventions, overall quality of theory can be established through its "contribution to the formation of meaning conventions in the interpretation community" (Apel, 1972, p. 29). The discussion section below identifies this social construction of knowledge in the scientific discourse as a crucial factor in establishing overall research quality.

Pragmatic Validation

In exploring strategies of pragmatic validation, it is useful to recall the idiographic nature of interpretive knowledge discussed above, whereby generalizability in the traditional sense of prediction and control of the system under investigation is not possible (Cilliers, 1998). An earlier illustration demonstrated how the analysis of deviant or nongeneralizable cases supported claims to validation. More specifically, the account of a student's experience with instructors that did not align with other patterns in the data validated the authenticity of the data-gathering situation. Yet, this complexity of the social reality observed demonstrated that the theory of instructors' influence as role models does not allow for the prediction of particular outcomes in individual cases. The focus of interpretive research is thus on fostering a deeper understanding of the social system under investigation rather than on the general application of theory to other contexts. This focus on understanding a particular context does not, however, eliminate the necessity to demonstrate that knowledge generated from its interpretation is also meaningful for similar contexts. The application of research results from one setting to another has been conceptualized as "transferability" (Miles & Huberman, 1994) or "applicability" (Lincoln & Guba, 1985). In the most general sense, we propose pragmatic validation as the process of determining whether the theory and constructs used or developed in a particular study can withstand prolonged exposure to the empirical reality, both in making the data and in handling the data.

In **making the data**, this exposure can be created through gathering data in a "natural setting" (Lincoln & Guba, 1985), that is, in a social context with all its complexities, tensions, and multiple viewpoints. The principal purpose of this strategy is to examine whether "the theoretical constructions that the researcher brings to the study" (Maxwell, 1992, p. 291) are applicable and meaningful in the social context investigated. For example, one of the explicit goals of the example study's data gathering in different cultural settings and with a diverse group of students was to expose whether the concept of accidental competence formation was meaningful across diverse educational settings (see also strategies such as immersion or embedded research, in Radcliffe, 2008).

Pragmatic validation in **handling the data** is concerned with the external customer, or the users of knowledge. Thus, validation takes the form of checking the impacts or benefits from using the knowledge in practice and thus places the "emphasis on a pragmatic proof through action" (Kvale, 2007, p. 126). On a more abstract level, pragmatic validation in handling the data means examining whether the theoretical interpretations generated from the investigation of a social context fit back into this or similar contexts, that is, whether "the findings are re-contextualized into the practice investigated" (Sandberg, 2005, p. 57). The idiographic nature of theory suggests the "tentative application" (Lincoln & Guba, 1985, p. 217) of knowledge to other contexts, which means that transferability cannot be established in general terms. Rather, the application of research results to other contexts must be assessed in each individual case. Lincoln and Guba (1985) propose the concept of fittingness "as the degree of congruence between sending and receiving contexts" (p. 124) as a measure for the applicability of findings to another setting. In the example study, the notion of accidental competency formation and the data-gathering process developed on the basis of this concept resonated with the participants, who perceived it as a meaningful opportunity to reflect on their own learning (Walther & Radcliffe, 2007a). The subsequent development of a teaching tool (Walther et al., 2009; Walther, Sochacka, & Kellam, 2011) to support student reflection in placement programs demonstrates that the "interventions based on the researcher's knowledge may instigate actual changes in behavior" (Kvale, 2007, p. 126), and thus supports claims to pragmatic validation.

Process Reliability

The notion of process reliability needs to be explored in the context of the epistemological assumptions underlying interpretive inquiries. The earlier Terminology of Research Quality section elaborated that, due to the complexity of the social systems under investigation, reliability cannot be achieved through repeated measurement. Before turning to possible strategies to ensure reliability, the following illustration briefly explores this aspect in the context of the example study and the instructors' influence as role models.

Illustration The earlier illustrations related a number of accounts of students who did not perceive their instructors as suitable professional role models. In some of the transcripts, though, this dynamic went beyond a factual analysis, and the sentiment of part of the discussion was very critical of the "academics" and exceedingly positive about the "real engineers." Subsequent analysis of the transcripts indicated that the dynamic of the focus group and my rapport with the students had possibly encouraged critical accounts of instructors. In fact, some of the data were called into question by the danger that certain segments of the focus groups had turned into "getting back at" instructors sessions. This dynamic prompted comments such as "I find that academics are very much down the line, whereas actual engineers are very lateral-thinking" (Cain, fourth-year chemical engineering student). Statements of such general nature were for the most part not supported by specific details or a critical incident.

These segments of the transcripts left a variety of possible interpretations for the data analysis. Statements such as Cain's above could, in fact, be reflective of qualities the instructors were lacking. However, they could be a product of the students venting their frustration caused by, for example, assessment. In other parts of this particular transcript, a certain cohort pride among the placement students for "having seen the real world" also became apparent and may similarly have motivated statements such as the one cited above. The point here is that in the absence of an actual incident account, one cannot conclusively interpret the data, since it might well be the reciting of a student "party line" (Kirk & Miller, 1986) or, more generally, the communication of an espoused belief.

> Yet, the repetition and uniformity of such contributions would traditionally suggest a certain degree of reliability. Superficially, the repeated statements point to deficiencies in the students' instructors, and a number of incident accounts did indeed back that up. Yet, one cannot draw on the frequency of the statements to support claims for reliability. This quixotic reliability ironically makes suspicious the data's capacity to accurately reflect the students' social reality.

This illustration shows that, in an interpretive inquiry, reliability as repetition or uniformity of data is not a suitable concept for assessing research quality. As an alternative, we propose the concept of process reliability to make the research as independent from random perturbations as possible. This goal can be achieved through the development and explicit documentation of dependable procedures in making and handling the data. In other words, "the criteria of reliability are reformulated in the direction of checking the dependability of data and procedures" (Flick, 2006, p. 371).

In **making the data**, process reliability is focused on strategies to support the collecting and recording of the data in a dependable way. Maxwell (1992) similarly conceptualizes "descriptive validity" as pertaining to the accuracy "of what the researcher reports having seen or heard" (p. 286). In the example study, this accuracy was achieved through the iterative development of specified data-gathering procedures. This process included the specification of a focus group protocol and the reflection on and explicit recording of lessons learned in facilitating the discussions between participants. This documentation also formed the basis for the training of the co-researcher for the Thailand part of the study (Walther, Boonchai, & Radcliffe, 2008). Kirk and Miller (1986) concur that "reliability depends essentially on explicitly described observational procedures" (p. 41). Process reliability is also concerned with the quality of the data recording, which can refer to the accuracy of the recordings and the production of transcripts. In the example study, digital recording technology was used and the recordings were transcribed verbatim. Accuracy was also increased through "transcription checking" (Gibbs, 2007, p. 98) by the researcher.

Similar to making the data, in **handling the data** the definition and documentation of interpretation procedures is pivotal in achieving process reliability. Several strategies were used in the example study to enable a "reflexive exchange about the interpretative procedures and about the methods of coding [to] increase reliability" (Flick, 2006, p. 370). One such strategy was the use of a chronological coding journal to record reflections on the data as well as the process of analysis; these records were used to construct the illustrations throughout this article. Standardized memos were also used to record the development of the individual categories of interpretation. A specific focus was on the precise, but naturally evolving, definition of the categories to provide a consistent guide for later coding decisions and avoid what Gibbs (2007) calls a "definitional drift in coding" (p. 98). Additionally, the various strategies of cross-checking to support the process of "constant comparison" (Glaser, 1969; Glaser & Strauss, 1967) were standardized and employed regularly in the development of the categories. The coding of the text at the two levels of topic and interpretive codes also supported the reliability of the interpretation. When analyzing the data, gradual abstraction through the two levels of coding ensured the grounding of the interpretations in the data. For the representation of the results, this procedure of coding allows "the data . . . to be explicated in a way that makes it possible to check what is a statement of the subject and where the researcher's interpretation begins" (Flick, 2006, p. 370).

Another way to improve the dependability of the interpretation of data is coding by several researchers to achieve interrater reliability. The focus of this process is, again, not the repeatability of the interpretation process but rather the mitigation of interpretive bias (see also Procedural Validation above) and the continuous dialogue between researchers to maintain consistency of the coding. In the example study, the data were not independently coded by several researchers, but development of the categories was regularly discussed with and reviewed by other members of the research team.

Discussion

The above sections developed notions of validation and process reliability appropriate to the epistemological and ontological assumptions underlying interpretive research. Drawing on the engineering metaphor of quality management and on discussions of research quality in the wider literature, these notions were developed into a process-oriented framework to support quality in interpretive engineering education research. This synthesis, combined with the grounding of the framework in a concrete example of interpretive engineering education research, explicitly bridges the perspectives of researchers from traditional engineering science backgrounds to current thinking in interpretive research. We intend the proposal to advance the discussion of interpretive engineering education research while being sensitive to the context and current practice of this emerging field. At the same time, we have endeavored to be mindful of the intellectual traditions of interpretive research in other disciplines. A key feature to achieve these ends is the process-oriented view of research quality we present here. This process-oriented view, combined with its specific application to an engineering education research context, frames the following three aspects of the discussion.

The first section below examines how the conceptions of research quality presented here relate to current developments in interpretive engineering education research. This part of the discussion explores a number of ways in which the current discourse is aligned with our proposal and offers a number of cautionary remarks on how implicit reductionist assumptions can create tensions in this necessary endeavor to frame interpretive research specifically in the engineering education context. The subsequent section examines how our framework could contribute to existing developments in the field of engineering education while avoiding the potential pitfalls identified in the first part of the discussion. These considerations have profound implications for engineering education research practice, in terms of both conducting and publishing research. These implications are discussed in the last section.

Current Discourse about Quality in Interpretive Engineering Education Research

This article is set in the context of the emerging discipline of engineering education research and related discussions on appropriate research approaches and ways of assessing quality in these various types of inquiries. While the concerns for research quality frequently voiced in this context are important and motivated this article, in the following we argue that this very discourse is still in the process of negotiating tensions between the implicit assumptions of engineering research and the conditions of the interpretive inquiry.

According to Borrego (2007b), the increased awareness of research quality in the field has led engineering education to "a point where standards of rigor can be discussed, defined and enforced" (p. 14). In this regard, Fink, Ambrose, and Wheeler (2005) suggest that "educational research may use methods that differ from the quantitative methods familiar in traditional engineering research, but it can be carried out and evaluated with the same standards of rigor"

(p. 189). Shulman (2005) argues in the same vein for the adoption of "standards of rigor . . . that we have traditionally applied to the work of engineering itself" (p. 11).

The argument presented here aligns with these contributions, in that interpretive work should be judged against high expectations of quality and that engineering thinking can contribute to approaches that are appropriate to the specific context of interpretive research in engineering education. The development of the notions of validation and reliability from a fundamental congruence with the concepts of accuracy and precision and the use of the engineering metaphor of quality management are expressions of this intent.

There is, however, a certain danger that calls for "standards of rigor" could carry implicit ideals of quantifiable benchmarks of research quality that are common to the traditional engineering sciences. As discussed above, the nature of the problems investigated in the interpretive paradigm precludes the definition of such measures in principle: "quality in qualitative research cannot be reduced to formulating . . . benchmarks for deciding about good and bad use of methods" (Flick, 2006, p. 384).

This tension suggests that it might be problematic to burden the current development in the community with assumptions that are either implied by the unintentional use of reductionist language or even explicitly advocate criteria of rigor that are only applicable to traditional engineering research. Such a discourse could constitute a significant impediment for the development of approaches to interpretive research quality that are specific to the engineering education context and, at the same time, appreciative of, but not limited to, the intellectual traditions of the interpretive inquiry. To account for these intellectual traditions, some engineering education researchers have begun to embrace alternative criteria for interpretive research quality (Leydens et al., 2004; Matusovich, Streveler, & Miller, 2010).

As discussed in the Terminology of Research Quality section, considerations of alternative criteria enrich the discussion of interpretive research quality in engineering education and generate sensitivity for the particular assumptions that necessitate a departure from narrow applications of traditional engineering science conceptions of research quality. The adoption of alternative criteria may, however, be problematic if engineering education researchers were to implicitly strive for a quantifiable standard or if these concepts were translated into a toolbox approach that advocates the use of a minimum number of methods (Creswell, 1998; Leydens et al., 2004) to ensure rigor. Considering the range of strategies that can be used in any specific research project, it is equally untenable to determine a particular number of strategies that would be sufficient to ensure the overall trustworthiness of the research.

The following demonstrates this point using the example of authenticity of the data-gathering situation (Flick, 2006), which was suggested as a means to support claims to theoretical validation. In the example study, the natural setting (Lincoln & Guba, 1985), as a criterion for research quality, was achieved through strategies such as prolonged interaction with participants (Creswell, 1998) and the establishing of a good rapport (Glesne & Peshkin, 1992). On the one hand, this authenticity enabled a unique access to students' shared lived experiences – they were willing to share unfiltered, critical experiences about their instructors. On the other hand, this dynamic also potentially compromised the validity of other parts of the data – the students at times also vented negative feelings concerning their instructors that were related to other causes and did not necessarily reflect their lived reality (see also Glesne & Peshkin, 1992, on "backyard research"). In other words, it is problematic to decide how much authenticity is enough, or even too much. In more general terms, it becomes clear that the mere inclusion of one or several quality strategies in a particular inquiry does not allow for a reasonable judgment of research quality.

We proposed the Quality Management framework as a way of overcoming the limitations of both the intention to formulate universal standards of rigor or the attempt to define a quantifiable toolbox of quality methods. To expand this understanding beyond the necessarily limited aspects drawn from the example study, the paragraphs below explore how the proposed framework might be applied to wider engineering education research practice. The tensions and challenges within the context of this emerging research field discussed above form a particular focus of this exploration.

A Framework to Foster Quality in Interpretive Engineering Education Research

The main function of the proposed Quality Management framework is to locate and explicate the use of strategies to foster quality throughout the research process. In line with the previous discussion relating to the unattainability of defined standards of quality, we do not intend the framework to serve as a basis for the development of prescriptive, recipe-like models of quality assurance for the various types of interpretive engineering education research. Rather, the framework is offered as a guide for researchers to systematize and explicate their quality efforts in the context of a particular inquiry. To support this exploration, the typology of aspects of research quality (see Table 1) presents the meaning of the types of validation and of process reliability for each of the research stages of making and handling the data. Drawing on the literature, individual strategies were situated within this matrix.

For other interpretive studies in engineering education, this framework can be used to explore which aspects of overall validation a particular quality strategy promises to address. More specifically, it can guide the discussion of questions such as: Why is this strategy appropriate to my research setting? Where in the research process does it fit? What does this strategy fundamentally achieve to improve research quality in this particular context (and what are its limitations)? Why is it justified or beneficial to select a particular strategy and not others?

Exploring these questions serves two fundamental purposes, both of which are essential in establishing overall research quality: the reflective documentation of the research process and, based on this documentation, the explicit communication of actual research practice in the publication of results.

The systematic documentation of the actual research process includes both the data gathering and the development of interpretations. In the context of the example study, a log trail was used throughout the entire study to record "where the ideas and theories came from" (Richards, 2005, p. 198). The immediate benefit of such reflexive documentation (Sochacka, Walther, Jolly, & Kavanagh, 2009) is increasing the dependability of the process of interpretation. In the example study, the systematized interpretation procedure and the standardization of category memos provided a reliable guideline for consistent coding of the transcripts. Additionally, the coding journal recorded "reflections on [the researcher's] role in the project, the ideas . . . discovered . . . and how they seem to work with the data" (Richards, 2005, p. 22). In line with the core tenets of quality management, the quality "of the whole research process can be developed by its reflexive documentation" (Flick, 2007).

Due to the complex nature of the social systems under investigation, a dependable research process cannot, in principle, achieve an absolute measure of research quality (Gronlund & Linn, 1990). Cohen et al. (2000) suggest that "validity, then, should be seen as a matter of degree rather than as an absolute state" (p. 105), an insight that is familiar to engineers in the context of quality management.

Research quality thus needs to be assessed relative to the research context and the individual research approach. Brinberg and McGrath (1985) assert that “validity is not a commodity that can be purchased with techniques. . . . Rather, validity is like integrity, character and quality, to be assessed relative to purposes and circumstances” (p. 13). This statement suggests that the appraisal of quality involves an element of judgment and thus ultimately shifts the focus of the assessment of research quality to the consumers of the research, that is, to the discourse within the relevant research community. For the dissemination of research, this focus on the research community entails that peers who assess the research need to be provided with sufficient contextual detail to be able to judge the quality of both procedure and the findings. Based on the reflexive documentation component of the research quality framework, this step necessitates the explicit demonstration of the actual research procedure. This explicit demonstration includes, for example, the description of the interpretive development of the results on the basis of the discussed reflexive documentation. As discussed in the Communicative Validation section, this view on research quality means that “validity claims are tested through the ongoing discourse among researchers and, in this sense, scientific knowledge is socially constructed” (Mischler, 1990, p. 415).

Implications for Interpretive Research in Engineering Education

The previous paragraphs demonstrated that quality in interpretive research must be established through the reflexive documentation and explicit demonstration of the research process. This suggestion echoes the call for “explicit engagement with [research] methodologies” (p. 186) voiced by Case and Light (2011) in the recent centennial edition of this *Journal*. The engineering concept of quality management provides a flexible yet systematic framework for fostering quality in the various stages of the research. The following discusses the specific implications of the socially constructed nature of knowledge for the role of consensus in the research community with a particular view to publication practices.

The authors of a recent editorial in this *Journal* asserted the need for “a rigorous research-based approach to our educational system, similar to the way in which research is performed and used in the traditional engineering disciplines” (Journal of Engineering Education, 2006, p. 259). For the interpretive inquiry, we have discussed a number of parallels to establishing rigor in traditional engineering research but also identified a number of significant differences. Due to the interdisciplinary character of engineering education, these tensions have profound implications for the definition of accepted knowledge within the research community. To explore this further and conclude our discussion about establishing overall research quality in interpretive engineering education research, the following examines the crucial role of consensus within the research community.

Some authors view consensus as an indicator of the degree of development of a discipline (Pfeffer, 1993). In engineering education, the debate is similarly concerned with attempts to “increase rigor and consensus in engineering education” (Borrego, 2007a, p. 93). This increase in consensus is associated with high journal acceptance rates and short publications. In this regard, it is important to distinguish two aspects of consensus: consensus concerning the accepted ways in which research is conducted to produce results of acceptable quality, and consensus relating to knowledge claims produced in a particular inquiry.

The first aspect of consensus concerning research methodology can be developed through more publications that explicitly describe how high-quality research was carried out in that particular investigation. Case and Light (2011) stress that making such questions of methodology explicit is necessary “in order for the quality and scope of research to continue to develop”

(p. 186). As a notable example, Matusovich et al. (2010) explicitly discuss specific aspects of research quality and associated strategies. In particular for interpretive approaches, which are unfamiliar to researchers from a traditional engineering background, Borrego (2007a) argues that "there is value in explicitly naming and referencing the criteria applied" (p. 17). As with the Quality Management framework presented here, such efforts to make issues of quality in interpretive research explicit could lead to the development of flexible typologies of research approaches (cf. Heywood, 2005) that include research stages, appropriate facets of quality, and associated quality strategies.

The second aspect of consensus concerning the agreement about specific knowledge claims produced in interpretive research differs significantly from traditional engineering research. The need to socially construct knowledge in the interpretive tradition entails that publication cannot merely be the presentation of validated results but becomes part of the process of validation (Mischler, 1990). Establishing research findings as accepted knowledge thus entails "confronting ideas with data as well as argument" (Kirk & Miller, 1986, p. 79). For research practice in an engineering education community that embraces "both quantitative and qualitative research" (Lohmann, 2008, p. 1), this requirement means that longer publications are not necessarily a sign of how far the discipline is removed from a desired high-consensus state. On the contrary, longer publications are necessary to give room for the explicit description of the individual research processes; these descriptions allow the research community, as the customers of research, to judge the quality of the knowledge claims presented. The ultimate integration of knowledge claims into the cumulative body of knowledge is dependent on the debate about their trustworthiness (communicative validation) and usefulness (pragmatic validation).

These conclusions about consensus have two implications for the engineering education community. First, publications of interpretive research should include detailed and reflexive descriptions of the research and interpretation process. Second, assessing research quality from a process perspective requires ways to systematize aspects of research quality within the diverse methodological approaches used in this emerging field.

Reinforcing these two points, we close by quoting the sociologist Robert Merton (1957), who described a similar struggle toward higher quality interpretive research in his field:

> This part of our report, then, is a bid to the [engineering education research] fraternity for the practice of incorporating in publications a detailed account of the ways in which qualitative analyses actually developed. Only when a considerable body of such reports is available, will it be possible to codify methods of qualitative analysis with something of the clarity with which quantitative methods have been articulated. (p. 444)

Conclusion

We developed a systematic, context-sensitive, and process-oriented framework for fostering and demonstrating research quality in interpretive engineering education research. The framework draws on concepts from a wide range of disciplines, while being grounded in concrete engineering education research practice by using a specific example study that illustrates key points of the argument. To this end, a prior interpretive inquiry into engineering students' professional formation (Walther, Kellam, et al., 2011) was presented with relevant, but necessarily reduced, details of the research process and the results in the form of selected categories of interpretation and student quotes from the data.

Our framework is intended to be sensitive to and grounded in the current practice of the emerging discipline of engineering education research. The proposed approach thus tries to overcome some of the challenges experienced by engineering education researchers from traditional engineering backgrounds by drawing on engineering-specific knowledge to develop a new, pragmatic approach to research quality in the interpretive inquiry.

As a first step in this process, we developed concepts of validity and reliability that are appropriate to the epistemological and ontological assumptions of the interpretive tradition from their fundamental congruence to the notions of precision and accuracy that are more familiar in engineering.

On the basis of these concepts, we drew on the engineering metaphor of quality management to propose a process-oriented framework of research quality. This framework consists of a stage model of the research process and a typology of fundamental processes of validation, as well as the notion of process reliability. In mapping the typology across the research stages, quality strategies can be explicated in their essential contribution to supporting knowledge claims produced in the interpretive inquiry.

In exploring the implications of the proposed approach for engineering education research, the discussion framed the process-oriented view of quality in the context of the current discourse in the field around rigorous interpretive research. More specifically, we explored how the current calls for rigor and the process of embracing alternative criteria can inform the process of developing more systematic approaches to research quality.

On the basis of the potential contributions and possible pitfalls identified in this discussion, the article then explored ways in which our proposal can be used in a wider range of interpretive engineering education studies. More specifically, the framework explicates approaches to research quality specific to a particular inquiry, supports their systematic application, and facilitates their explicit communication to the research community.

In this way, the proposed framework shifts the assessment of research quality from solely being part of the research process to also relying on the discourse of the research community. This shift has profound implications for the nature of consensus concerning the cumulative and socially constructed body of knowledge that is produced in interpretive research. While a consensus concerning systematic ways of conducting and evaluating research is desirable, we argue that actual knowledge claims need to be presented, with rich detail of the research process, and ultimately validated through both data and argument. Publication practices thus must account for the inclusion of such detail, and the research community must further develop systematic views of interpretive research quality that account for the diversity of research approaches embraced by the emerging field of engineering education research.

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