AC 2008-569: APPROACHING QUESTIONS OF RESEARCH QUALITY IN AN INTERPRETIVE INVESTIGATION OF ENGINEERING STUDENTS' COMPETENCE FORMATION

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Approaching questions of research quality in an interpretive investigation of engineering students' competence formation

Abstract

This paper introduces an interpretive research approach as one possible way to investigate complex social aspects of engineering education. With the aim of exploring questions of rigor in the interpretive enquiry, we present the details of a study into competence formation of engineering students. The study employed focus groups with engineering students from Germany, Australia and the US, to investigate the phenomenon of Accidental Competency formation. After reviewing research design, data gathering and interpretation procedure we present examples for the different types of findings produced in the interpretive enquiry. These results take the form of explanatory patterns, rich descriptions and an applicability study. Drawing on examples from the research, we offer the following three propositions as a starting point for discussing the quality of interpretive research in engineering education: (i) traditional criteria of validity and reliability are not directly applicable to the interpretive enquiry; (ii) alternative criteria such as trustworthiness or authenticity do not offer an overall measure of research quality; (iii) to mitigate this, we propose a process view of establishing research quality in a documented and demonstrated procedure.

1. Introduction

Engineering education research is commonly viewed as an emerging discipline.[1-5] The current debate is concerned with possible research areas of interest to the discipline,[5, 6] appropriate research methods[7, 8] and ways of conducting research of acceptable quality.[1, 4, 9] In this context Borrego[4] asserts that "the field of engineering education has not yet developed its first paradigm" with the term paradigm relating to "common terminology, methodologies, and standards of rigor."

Due to the interdisciplinary nature of engineering education research, approaches and elements from both the engineering sciences and from fields such as the social sciences and educational research have been advocated.[3] This paper argues that an interpretive research approach is one appropriate way of investigating particular questions within engineering education. To illustrate this, we present an interpretive study into the formation of engineering students' competence[10-12]. This includes details about the research design, the data gathering, the interpretive analysis and examples of the types of results that were produced. Drawing on examples from this study, the discussion explores potential ways of establishing rigor in an interpretive enquiry. In particular, we offer the following three aspects as a starting point for a discussion possible ways to evaluate quality of interpretive engineering education research. First, we demonstrate that traditional conceptions of, for example reliability, are not appropriate to the nature of the research. In the second step, we draw on the literature from research traditions such as anthropology, the social sciences and education to explore alternative concepts such as trustworthiness and authenticity. Exploring the notion of authenticity in relation to an example from the data revealed that an application of such alternative criteria in the traditional sense of quantifiable benchmarks is not

possible. As the third point, we thus propose that establishing trustworthiness as a measure of rigor in interpretive research needs to take a procedural view by documenting and explicitly demonstrating the actual research process.

2. Interpretive research to investigate the social system of engineering education

The interpretive paradigm pertains to research that investigates complex social systems[13] through observation (by direct or indirect means) and subsequent interpretation of social contexts[14, 15] that are constituted by the shared lived experience of individuals. To clarify this notion further, we begin by examining the choice of the denotation 'interpretive' more closely.

We deliberately did not choose the familiar terms of qualitative research, as set against quantitative research. This would immediately evoke a distinction according to the use or absence of numbers, which is not particularly informative in this context.[16] To get a clearer understanding of the interpretive approach, we need to recognize that some research problems in engineering education are in their nature essentially different from traditional engineering research.[3] The core of this difference lies in the complex nature of the social aspects of engineering education under investigation. More specifically, social reality emerges form multiple and varied interactions of individuals.[13, 17] This emergent[13, 18] and inter-subjective reality[19-21] is the very object of research and can in its nature not be represented in simple rules or deterministic correlations. The focus of interpretive research is thus, to understand the intricacies and patterns in the data and "place them in illuminating connection with [the] concepts that theorists have fashioned to capture the general features of social life."[22] This process of understanding and of generating theory depends on the interpretation of accounts of individuals lived experience,[23] "less important is whether or not, or at what level of sophistication numbers are employed to reveal patterns of social life."[16] Studies that employ quantitative methods to generate knowledge about social aspects of engineering education, can also involve substantial interpretation. In these cases "deciding what to count as a unit of analysis is fundamentally an interpretive issue requiring judgment and choice."[16]

This understanding of the interpretive enquiry carries with it a number of characteristics that are important in conducting research and in approaching questions of research quality.

- *Interpretation* as a research process implies judgment and is thus different from observation in the materialistic sense. However, the assumption that knowledge is not directly "imposed by the structure of empirical reality"[16] does not suggest an extreme relativistic view that denies any form of observable reality. The social aspects that emerge from the complex interactions of individuals constitute an observable reality.
- *Interpretation* suggests that the researcher is embedded into the social context under investigation. Thus mutual influences between the social context and the researcher in the process of observation need to be considered.
- *Interpretation* assumes that the researcher makes sense of the world within existing, socially constructed frameworks. This means that the knowledge needs to be generated in a communicative process.

Together, these three points suggest that it is possible to produce agreed upon knowledge about social reality and that this production of knowledge needs to take the form of a rigorous process of interpretation.

3. Overview of the study

As an example of an interpretive investigation in the field of engineering education, we present a study into competence formation in engineering students.[11] Through the lens of Accidental Competency formation, this study employed a holistic view on the educational process to investigate how various educational influences and factors from the wider educational context interacted to form student competence. The complex interactions[12] were found to have positive (Accidental Competencies) and negative (Accidental Incompetencies) impacts outside the scope of intentional teaching activity.

This phenomenon was investigated in focus groups[24-26] with engineering students using critical incident techniques.[27-30] Additionally, critical incident data from ongoing self-recording[31] of a cohort of industry placement students was collected. Using the qualitative analysis tool NVivo7, the data was subsequently analyzed for categories of educational influences, work situations and competencies developed by the students.

3.1 Data gathering

The data gathering consisted of nine focus groups with a total number of 40 participants from Germany, Australia and the US. Additionally, nine students participated in the weekly self-recording over a semester long placement program.

The respondents were graduate engineers or final year engineering students who had at least six months of industry experience through formal placement programs. This was to ensure that the participants were sufficiently close to their educational experience as to be able to recall detailed incidents. Yet, the students' industry experience ensured the relevance of the competence concepts for professional engineering practice.

In order to obtain a diverse data set in the sense of an exploratory study, the participants for the focus group were selected from a wide range of innovative placement programs at different institutions in Germany, Australia and the US. Focus groups were conducted with:

- Graduates from the Technische Universität Darmstadt (Germany), who had completed a structured six month internship program during their time at university and had worked for up to a year in different engineering fields after graduation.
- Final year students from the University of Queensland (Australia) who had completed a six month industry placement program that combined work experience with the completion of an industry based final year thesis.[32]
- Students at Purdue University from the Engineering Projects In Community Service program (EPICS),[33, 34] the Global Engineering Alliance for Research and Education (GEARE)[35, 36] and the Co-op program.[37]
- Final year students from the University of Georgia who had gathered their industry experience in vacation work and unstructured internships.

The focus groups were based on a semi-structured protocol using critical incident techniques[27-30] to elicit instances of accidental learning. Critical incidents are detailed accounts of real-world experiences of the participants. In the area of competency research, critical incident techniques were shown to be more reliable than, for example, expert's panel methods or respondents' self assessment[28-30]. The focus on detailed descriptions of incidents from the students' time in practice or at university mitigates the influences of "espoused beliefs"[38] or inaccurate self-assessment on the quality of the data.

In the elicitation of critical incident accounts, the students' concrete or intuitive recall of their experiences was prompted with the help of specific triggers. A list of statements was used to explore moments of competence anomalies,[39] where the student's performance experienced in practice did not match their competence expectation (Example: "When working on this task in the company, I suddenly realized that I can do this even though it was never taught to me!"). The reflection was thus not guided by abstract competency descriptors as not to restrict the participants to preconceived concepts of competence. The interactive group discussion that followed the presentation of an initial account by one participant allowed the students to explore their shared experiences on the level of concrete examples (for a more detailed description of the procedure see[39]). With the students' informed consent, the focus groups were digitally recorded and transcribed verbatim. The cohort of placement students who participated in the semester long self-recording followed similar trigger statements. They recorded and reflected on critical learning events during their time in industry and related these back to their prior learning at university. The self-recording consisted of a weekly submission of one complete account of a critical incident each week for twelve weeks.

3.2 Data Analysis

The focus transcripts were analyzed using the qualitative data analysis tool NVivo7.[40-42] The text was coded on two levels of increasingly abstract interpretation from what Geertz[22] calls "experience-near" to "experience-distant concepts".

As illustrated in Figure 1, the level of topic coding included clusters of *educational influences* and *work situations* (for clarity the names of the coding clusters and categories are italicized). The clusters comprised subordinate categories to describe specific educational influences or work situations. This level of descriptive coding was based on *a priori* set of clusters and categories that were adjusted in the course of the analysis. The categories captured and categorized 'what the respondents talked about' - whether the students' accounts were, for example, concerned with exams or reported interactions with their instructors. This coding was largely descriptive and did not require significant interpretation on the researcher's part.

Based on the topic coding, the transcripts were analyzed for categories of *competencies*. This level of interpretive coding derived abstract descriptions of the competencies developed from interpreting the students' accounts in the context of the entire focus group discussion. The interpretive coding followed a grounded theory approach[17, 43, 44] and the categories emerged iteratively from the data. First interpretations or explanatory patterns, which were often vague and ill-defined, were coded "*in-vivo*"[45], using characteristic terms from the respondents'

utterances. The coding at this stage consisted of a collection of accounts that 'somehow seemed to belong together'. From these, more and more defined categories were developed through the iterative process of "constant comparison."[43, 44, 46]

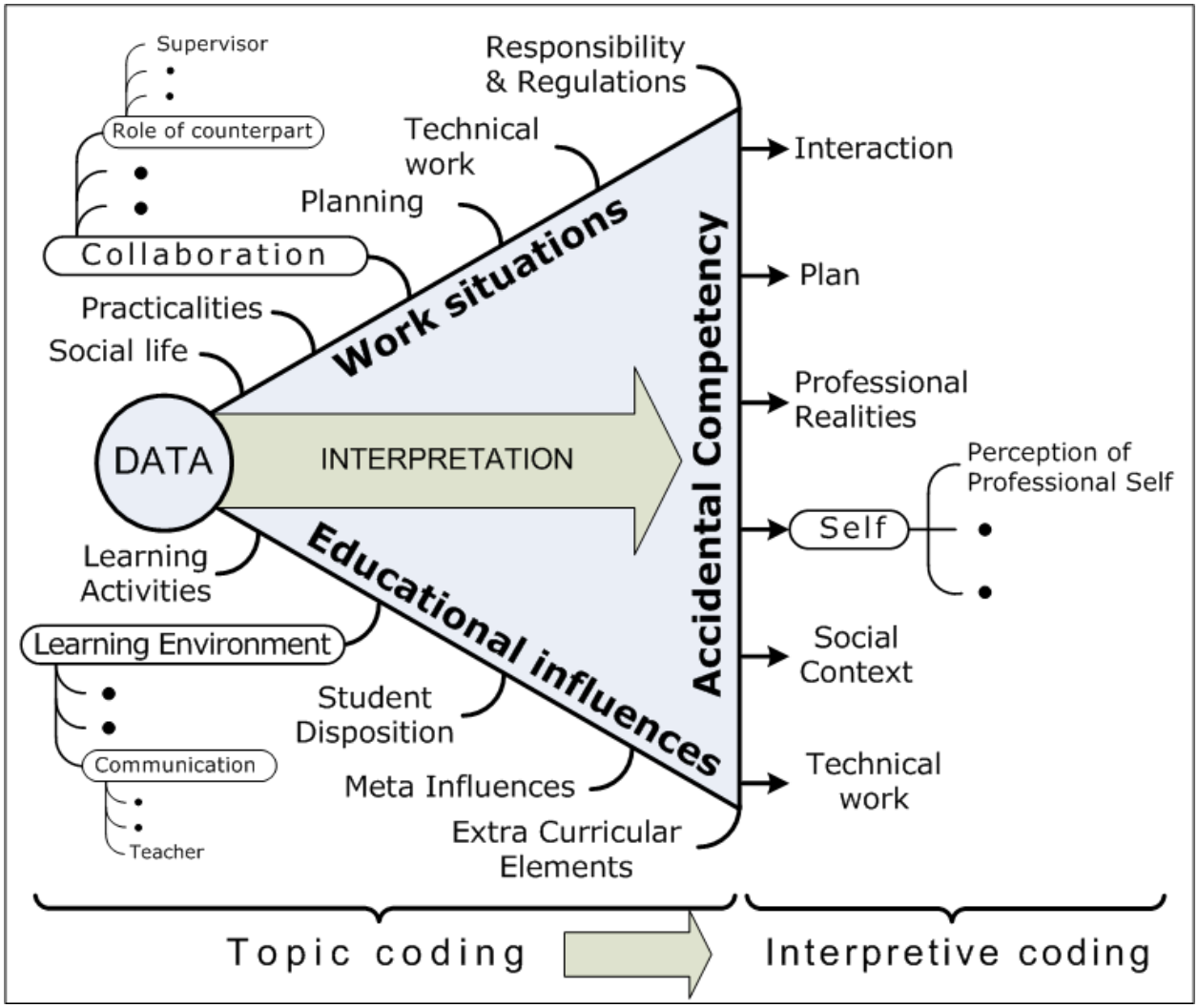

Figure 1: Coding model - topic and interpretive clusters with examples for subordinate categories

Constant comparison is defined as a systematic procedure "through which researchers engage in detailed analytic processes that require repeated confirmations of potential explanatory patterns discovered in the data."[43] The procedure consists of iterations of re-reading the transcripts, comparing all accounts coded for a particular category or cross-comparing the accounts of related categories. At each stage of the process the development of the categories was recorded in standardized memos. For each category a linked memo was created as a defined reference for future coding decisions. The memo format contained an abstract (and naturally evolving) definition of this category, a discussion of its relation to and distinction from connected categories within the cluster and the recording of peculiarities, exceptions or 'outliers'. In addition, a chronological coding journal was used to record the overall development of the coding structure including the evolution of clusters and categories, observations about interesting pieces of data that did not fit into a particular category and hunches or ideas about possible

explanatory patterns. Apart from ensuring cohesiveness of the development of the interpretations, the coding journal also established a log or audit trail. In the presentation of the research findings, such a log trail can be used to illustrate the development of categories, present alternative interpretations or establish an accurate description of the actual analysis process. From this process of cross-comparing and defining of categories, a coding structure of clusters and categories developed that proved stable in coding further transcripts.

An example for this iterative procedure was a number of accounts that were concerned with students' interactions with university teachers on the one hand, and industry supervisors on the other hand. These quotes seemed to belong together and the students' use of the phrase 'academics vs. real engineers' captured the commonality. From collecting accounts in this in-vivo category (See Figure 2 below), it became apparent that on a more abstract level, the accounts were concerned with the students process of defining their own role as professional engineers according to their perception of role-models. Thus, the category was finally conceptualized as *Perception of Professional Self*. In Section 3.4.2 we examine this category, the contributing influences and related competency categories in more detail.

3.3 Overview of the results

This section is intended to give an overview of the outcomes of the study and illustrates the types of results produced within the interpretive approach. However, within the scope of this paper we cannot give a comprehensive account of the findings and thus focus on exemplars that are illustrative in approaching questions of quality of interpretive research in the later part of the paper.

The following gives an overview of three fundamental types of results. These include (i) explanatory patterns of student competence formation which are embedded in the coding structure (See Figure 1) and are illustrated by (ii) rich, thick situational descriptions and quotations from the respondents' accounts and (iii) the transfer of the results or concepts of the research into a different context in the form of an applicability study.

3.3.1 Explanatory patterns

The coding structure presented in the following, represents explanatory patterns in the sense that they allowed categorizing the influences that interacted to form students' competencies and the different types of outcomes. However, this does not imply that the individual incidents of competence formation follow a deterministic pattern, which can be described for all cases. This applies particularly to the different national and cultural settings in which the research was conducted. According to the exploratory character of the study, the complexity of competence formation expressed in the concept of Accidental Competencies was found across all data sets. The specific categories of competencies or influences, however, where not distinguished according to the national backgrounds of the respondents. For example, the influence of the students' interaction with their teachers played a significant role in all the focus groups conducted. However, the specific impact of this influence was different in the different transcripts. To systematically analyze these differences and determine whether they can be

attributed to the national background or the particular placement programs in which the students participated was beyond the scope of this project.

The coding structure illustrated in Figure 1 contains the clusters of topic codes to categorize *educational influences* and types of *work situations.* The subsequent interpretation yielded clusters of categories to systemize types of *Accidental Competencies*.

The educational influences were captured in clusters for different *learning activities*, influences from the *learning environment,* aspects of the *students' disposition,* so-called *meta influences* and various *extra-curricular elements*. The cluster of learning environment for example contained a category for *communication* and as a subordinate category for the communication between the students and their *teachers* (Figure 1).

Similarly, the work situations were grouped in clusters of categories of accounts where the students described ways in which their work impacted on their *social life,* various *practicalities* of the industrial context, instances of *collaboration* in the workplace, aspects of *planning*, types of *technical work,* and issues concerned with *responsibilities and regulations.* Each cluster again contained categories and subcategories, for example, to classify collaboration with various types of *counterparts* such as the students' *supervisors* in the workplace.

From the interpretive coding for competencies, emerged six clusters of competencies related to *interaction*, *planning*, dealing with *professional realities*, the *self*, the *social context* and *technical work*. An instance of a competency from the self cluster was the *perception of professional self* to describe how the students' image of a professional engineer impacted on their overall performance in the workplace.

3.3.2 Example of competence formation: Influence of teachers as role models

One way to gain an understanding of the complex processes beyond the categorization of influences and competencies, is to examine the richness and complexity of the data through what Geertz[47] calls "thick descriptions". This "tracing of narrative trajectories through the system"[18] can for example mean to consider a particular competency node as one outcome and examine the range of contributing influences and their interactions.

As an example, the following section examines the formation of the students' professional self-perception from a multitude of influences as illustrated in Figure 2. The interpretation of the transcripts revealed that a range of educational influences and work situations interacted in a complex way to form the students' perception of their role and qualities as professional engineers. With respect to overall competence or performance in the workplace, this competency was found to be connected to several other competency categories in the sense that it organized and contextualized other competencies in their application to a specific context.

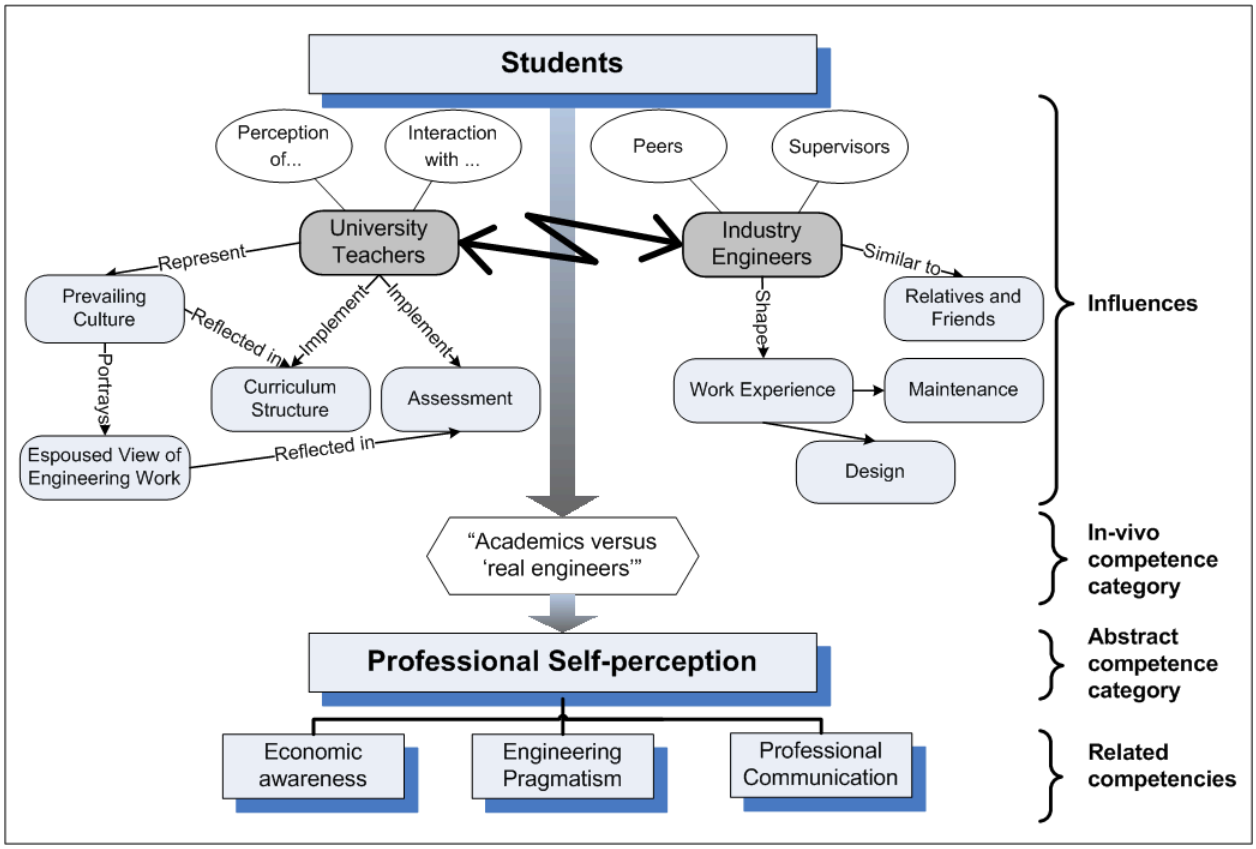

Figure 2: Influence model – the influences interacting in the development of students' professional self-perception and connected competence categories

The influence model presented in Figure 2 is not intended as a comprehensive representation of the full range of interactions that contribute to the formation of this particular competency. The limitations of the figure and the further reduction in the description below are not only due to the scope of this paper; the complex nature of the system under investigation precludes a comprehensive and systematic representation. Chillier[18] aptly states that "to describe a complex system you have, in a certain sense, to repeat the system". It is thus helpful to view the illustration as one snapshot of a network of such influence models which "are in a state of mutual simultaneous shaping."[48] Every node could, in another context, be the center of an equally intricate network. For the purpose of this paper we focus the subsequent description on examples that are illustrative in approaching questions of research quality in the later section.

A dominant influence in the development of students' "professional way of being"[49] was their experience of differences between their university teachers and their supervisors or peers in industry. When reflecting on their industry experience the students reported a number of competence anomalies with reference to their interaction with or perception of engineering academics. One example is the understanding of engineering work that is commonly portrayed in the university context. Hasslam, a final year Mechatronics student, describes an incident during a design project where the students' attempts to consider economical aspects of the design did not agree with the teacher'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 […] lecturer […] takes one look and says 'I don't like this […] because it is not professional'."

In other transcripts, this approach to engineering was manifest in the curriculum structure or individual assessment pieces and led to negative student perceptions of an instructor as a person who *"has all these little fiddly things he likes to stick to, this nice little protocol he likes. Everything's gotta fit into the box."* (Hasslam)

During their time in industry, the students experienced a more flexible and pragmatic approach to engineering within the economical constraints of the work context. The respondents describe this variably as: *"The thing I got from the work: If it works and if you can afford it, go for it"* (Hasslam) or *"I just have to make it work"* (Cain, 4th year Mechanical). Consequently, the students' perception of their industry supervisors was shaped in a very different way. In describing an industry supervisor Adam (4th year Mechanical) states, *"My boss, he is very good at what he does […] he has all the experience. […] He can picture how things come together."*

However, we should also report that not all students related such negative impressions of their teachers. In another part of the transcript Hasslam recounts that *"most of the lecturers in the mechanical engineering department have some ties into the real world. So they have something they can relate to."* Acis (4th year Mechanical), for example, remembers a particular academic as *"a really helpful person"* and at the same time admits to a prevalent student bias, referring to *"a lot of stereotypes […] of guys with comb-overs and poor social skills."*

When forming the perceptions of their professional self, students aspired to the qualities they associated with 'real engineers' and rejected attributes they considered typical of 'an academic'. In this process some students adopted a number of qualities that fell into other competence clusters such as *economic awareness, engineering pragmatism* or *professional communication* (See Figure 2). In that sense the professional self-perception had an organizing and contextualizing function with respect to competencies in other clusters.

3.3.3 Applicability study: Development of a teaching tool

A very different type of result in this project emerged in the research process and could not necessarily have been foreseen from the beginning. The underlying concepts and the data gathering method proved highly beneficial for the participants and were subsequently developed into a teaching tool to support students' reflection during their participation in placement programs.[39]

This insight emerged from the continuous effort to improve the focus group protocol and technique through reviewing the transcripts for participants' reactions to certain triggers and also by asking the students informally for feedback and their perceptions of the focus group. From the student feedback it became apparent that they experienced considerable benefits from their participation, in that they realized new aspects of their experiential learning and were able to connect this to their prior learning at university. As an example, one student who had taken part

in a formal placement program that incorporated regular reflections as part of the assessment, reports this element of new insights he gained through the focus group. Without being prompted he interrupted his own account of a critical incident by stating: *"Yeah, that's something I had never really thought about!"* (Cain) The benefits of the student participation were in subsequent focus groups investigated systematically through the use of questionnaires.

4. Discussion: Approaching rigor in interpretive engineering education research

After reviewing the research process and the results of the study, we now turn to the question of how to ensure rigor or quality in such an enquiry. In the following we illustrate for the example of reliability, that traditional criteria of rigor are of limited use when considering the nature of the research. This leads into the exploration of the notion of authenticity[17, 50, 51] which has been proposed as an alternative criterion suitable to the underlying assumptions of interpretive research. The example of improving authenticity by developing a good rapport between researcher and researched demonstrates that alternative criteria of rigor can not be applied in the traditional sense of quantifiable benchmarks. This leads to the proposition that research quality needs to be established in a documented and demonstrated research procedure.

4.1 Traditional criteria vs. alternative criteria

Several authors point out that the fundamental assumptions underlying interpretive research pose special challenges in establishing rigor. More specifically, the application of concepts such as reliability in the traditional sense is not appropriate.[14, 16, 17, 20, 44, 52] Due to the discussed complexity of the social system under investigation reliability can not be achieved through repeated measurement. We want to illustrate this point in the example of the teachers' influence in the formation of students' professional self-perception.

Illustration:

We discussed above that individual university teachers played a significant role in the development of students' professional self-perception. One particular pattern resulted from a perceived contrast between students' university teachers and their supervisors in industry. The students did not perceive their teachers as suitable professional role models and through experiencing this contrast, started to reflect on their own role as professional engineers.

However, in some of the transcripts this 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'. In the subsequent analysis of the focus groups, we identified that the dynamic of the focus group and my[i)] rapport with the students (see illustration below) had possibly favored critical accounts of students about their teachers. In fact, some of the data was called into question by the danger that sections of the focus groups had turned into the 'paying out' of lecturers. This prompted comments such as *"I find that academics are very much down the line, whereas actual engineers are very lateral thinking"* (Cain). Statements of such general nature were mostly not supported by specific details or a critical incident.

For the data analysis this leaves a variety of possible interpretations. The statement could, in fact, be reflective of the lacking qualities of the instructors. However, it could also be the students venting frustration caused by assessment. In other parts of the particular transcript, a certain cohort pride among the placement students for 'having seen the real world' becomes apparent and could motivate statements such as the one cited above. The point here is, that in absence of an actual incident story, we can't conclusively interpret the data since it might well be the reciting of a student "party line"[16] or more generally the communication of espoused beliefs.

Yet, the repetition and uniformity of such contributions would traditionally suggest a certain degree of reliability. Superficially, the repeated statements point to deficiencies of the students' instructors and a number of incident accounts indeed back that up. However, we can't draw on the frequency of the statements to support claims for reliability. This effect, which Kirk[16] refers to as "quixotic reliability," ironically makes the data suspicious in its capacity to accurately reflect the students' social reality.

[i)] Where necessary the illustrations refer to the first person experience of the primary author in collecting the data.

This illustration shows that in the context of interpretive enquiry reliability as repetition or uniformity of data is no suitable concept to assess research quality. In response to this challenge, some researchers reject the application of traditional criteria in the context of interpretive research and propose alternative criteria such as trustworthiness or authenticity.[17, 50, 51]

4.2 Criteria vs. benchmarks

To further explore these alternative criteria, we examine the notion of authenticity in the context of the present study. Authenticity, as a measure of research quality, can be achieved through strategies such as prolonged interaction with participants and establishing a good rapport. The following illustration shows that it is not possible to define the achievement of such a criterion in a universal sense – in other words it is problematic to decide 'how much authenticity is enough (or even too much)'.

Illustration:
When discussing the students' experiences concerning university teachers in the focus group, my personal background inescapably impacted on the kind of information the students shared with me and how they presented this information – we discussed the embeddedness of the researcher in the social context above. In my case, the students were more likely to regard me as a 'fellow student' due to similar age, the shared experience of an engineering degree and the fact that I was in no cases involved in the teaching of any of their courses - in short, I had established a good rapport. Thus, the students were more likely to relate unfiltered, critical accounts about experiences with teachers to me compared to, say, to someone they are likely to perceive as a teacher. This special rapport allowed me unique access to particular aspects of the students' social reality such as their experiences with and perceptions of teachers.

> However, we illustrated above that this rapport or familiarity with the students also lead to a dynamic that might have prompted unsubstantiated negative accounts of the students' perceptions of their teachers. In an atmosphere of familiarity and trust students were not only relating unfiltered accounts of their experiences. At times they were tempted to vent some of their negative feelings that were potentially related to other issues. Such statements were thus not necessarily reflective of their reality. As a consequence, some of those accounts, especially if they were not substantiated by a critical incident, could not be considered as valid data in the subsequent analysis.

From this example it can be seen that it is clearly impossible to quantify in a general sense how much authenticity is enough to guarantee rigor in interpretive research. In contrast to traditional engineering research, where quantifiable standards of validity and reliability can be derived, the nature of the research problems in the interpretive enquiry precludes the definition of such measures. Flick[51] confirms that "quality in qualitative research cannot be reduced to formulating […] benchmarks for deciding about good and bad use of methods".

4.3. Establishing rigor through documentation and explicit demonstration of the research process

From the discussion of the two points above, it is evident that traditional criteria of rigor are not applicable to interpretive research. However, alternative criteria such as authenticity do not make any specific suggestions how to ultimately establish rigor or the quality of research results. A possible solution to this problem is to shift the attention from assessing the quality of research outcomes to ensuring the dependability of the research process. The concept of trustworthiness alludes to this approach in offering a holistic view[17] on the research "process as a whole."[52] This suggestion has a number of implications for the way interpretive research in engineering education is conducted and the way results are presented to the research community.

An implication for research practice is the need to systematically document the actual research process, including the development of interpretations, in order to record "where the ideas and theories came from." [45] We presented strategies such as an audit or log trail that have been suggested for this purpose. The immediate benefit is the increasing dependability of the process of interpretation. In our study the systemized 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 our role in the project, the ideas […] discovered […] and how they seem to work with the data". With respect to ensuring rigor in interpretive research this means that the quality "of the whole research process can be developed by its reflexive documentation."[52]

From the rejection of benchmarks discussed above, also follows that the assessment of research quality involves an element of judgment. Since the nature of the interpretive enquiry does not allow quantifying absolute standards, quality needs to be assessed relative to the research context and the individual research approach. Brinberg[53] asserts 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." This means that peers who assess the research need to be provided with sufficient contextual detail to be able to judge the quality of

the procedure and the findings. For the dissemination of the research, this entails the need for the explicit demonstration of the actual research procedure and the interpretive development of the results on the basis of the discussed audit trail. This means that the ultimate judgment about the quality of the research lies with the relevant research community. Mishler[54] points out that "validity claims are tested through the ongoing discourse among researchers and, in this sense, scientific knowledge is socially constructed."

5. Concluding remarks

The above has two profound implications on publication practices within the engineering education community. First, publications of interpretive research need to include detailed and reflexive descriptions of the actual research and interpretation process. And second, the notion of assessing research quality from a process perspective indicates the need to develop systematic approaches to quality control in interpretive research.

Mirroring these two points, we want to close in paraphrasing the sociologist Robert Merton[55] who described a similar struggle towards rigorous research in his field:

> "This part of our report, then, is a bid to the [engineering education] 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."

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