Confronting the methodological challenges of engineering practice research:

A three-tiered model of reflexivity

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Abstract: Reflexive practices allow researchers to think critically about how their disciplinary background, preconceptions and behaviours impact on the research process. With recent calls for increased rigour in engineering education research, reflexive practices are important because they provide ways to increase the trustworthiness of research findings. Developed in the context of engineering practice research (EPR), this paper presents a three-tiered model of reflexivity with the view to support engineering education researchers embarking on interpretive research approaches. Each tier of the model is introduced with an abstract description, an illustrative example that draws on a current research project, and a discussion of appropriate strategies to incorporate reflexivity into the research process.

Introduction

In recent years, the scope of engineering education research has broadened beyond questions relating to learning *per se,* to include the investigation of the practice of engineering in a wider societal and global context (Radcliffe 2006). In this paper, we call research concerned with the practice of engineering in social contexts 'engineering practice research' (EPR). This new field of research is also typically referred to as *Engineering Epistemologies*; as put forward in 2006 by the Engineering Education Research Colloquies (EERC) in a five-point research agenda to underpin the emerging discipline of engineering education (EERC, 2006). The purpose of EPR is to gain a deeper understanding of what constitutes engineering thinking, knowledge and competencies within social contexts now and into the future (Anonymous, 2006; Radcliffe, 2006). Knowledge generated from EPR has two main goals; first, to provide insights to the engineering profession and second, to inform engineering educators so that they may adequately prepare students for the challenges they will face as professionals (Anonymous, 2006). EPR, along with the four other lines of enquiry proposed by the EERC, is illustrated in **Figure 1**. Also presented are two potential beneficiaries of knowledge generated from EPR; the engineering profession and the engineering education community (including both researchers and instructors).
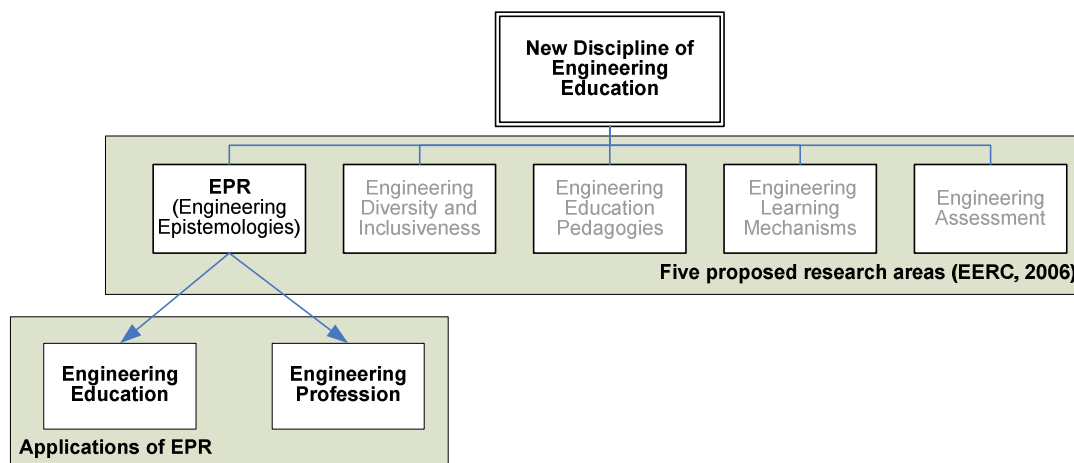
Figure 1: Positioning of Engineering Practice Research (EPR) within the 'new' Discipline of Engineering Education

Recent studies demonstrate the importance of social interactions in engineering practice (Trevelyan, 2008). Technical research approaches however, are not designed to investigate human behaviour issues. As a result, an increasing number of researchers are recognising that modes of enquiry typically applied to technical engineering research are not suited to the investigation of engineering in practice (Radcliffe, 2006).

Interpretive research approaches offer a means to capture the 'messy, hard-to-get-a-handle-on issues that confront [engineering] practitioners daily' (Radcliffe 2006). However, such approaches carry with them diverse challenges in terms of ensuring rigorous research (Koro-Ljungberg *et al.*, 2008). Some authors suggest that these challenges are further exacerbated for engineering education researchers because many are engineering faculty who have been trained in standards of technical, not interpretive, rigour (Borrego, 2007; Koro-Ljungberg and Douglas, 2008).

A central element in approaching the topic of rigour in interpretive research concerns the examination of how the researcher impacts on the research process (Findlay *et al.*, 2003). Typically referred to as 'reflexivity', these examinations require critical self-reflection of the researchers' disciplinary background, preconceptions and behaviours, as they relate to and influence the research project[1]. However while it is generally accepted that reflexivity is a defining feature of interpretive research (Denscombe, 1998; Bryman, 2001; Richards, 2005; Babbie, 2007), *how to do it* remains the subject of much debate (Gough, 2003).

In this paper we present a three-tiered model of reflexivity to assist engineering education researchers embarking on interpretive research. In doing so, we offer strategies aimed at increasing the trustworthiness, or, rigour, of the research process and findings. While the model described in this paper was developed as part of an EPR project, we hope that it will also prove relevant and useful to interpretive research projects in other areas of engineering education research, such as teaching, learning and assessment.

A current engineering practice research (EPR) project

The model presented in this paper was developed for a doctoral research project which focuses on an archetypical engineering problem – urban water management. The basic premise of this work is that the widespread installation of decentralised technologies, e.g. rainwater tanks in Australia and water meters in the United Kingdom, has fundamentally changed the set of variables that water planners need to understand in order to maximise socially, economically and environmentally sustainable outcomes. This is because, in contrast to conventional single-source approaches to urban water

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[1] Here it is important to make a distinction between 'reflection' and 'reflexivity'. Findlay *et al.* (2003) define reflection as 'thinking about' something after the event. Reflexivity, in contrast, is understood to involve a more immediate, dynamic, and continuing self awareness (Findlay *et al.* 2003). In this paper we use the term 'critical self-reflection' (Findlay *et al.* 2003) in an attempt to capture both poles of the reflection-reflexivity continuum.

management, the success of decentralised technological solutions depends not only on technical factors (e.g. rainwater tank size, fittings and connections) but also on a diverse range of social factors (e.g. extent and nature of policy support, and household acceptance and management). An interpretive research approach was determined as appropriate for this project to enable the investigation of the socially constructed nature of implementation processes and usage patterns associated with decentralised technologies. Specifically, the study aims to answer the following two research questions which were developed according to the realist approach proposed by Pawson *et al.* (1997):

1. What mechanisms for change are triggered by the implementation of decentralised technologies in the context of urban water management and how do they counteract existing water usage patterns? and,
2. What social and cultural conditions are necessary for these change mechanisms to operate and how do they vary within and between different contexts?

In line with the two main goals of EPR discussed above, it is envisaged that knowledge generated in this study will be useful both to engineering professional practice, as well as to engineering education (e.g. what do tomorrow's water engineers need to know in order to deliver sustainable solutions?).

To date the study has focused on the implementation of decentralised technologies in two contexts:
- The compulsory installation of water meters in the south east of the United Kingdom; and,
- The voluntary installation of rainwater tanks in south east Queensland, Australia.

Data collection for this project entailed interviews, surveys, and document analyses. Informants included a range of professional people such as engineers, architects, town planners, business people, as well as residents. Data was analysed using thematic techniques within the qualitative software analysis package, NVivo.

Model development

This study is being undertaken by a graduate Environmental Engineering PhD student (the primary author of this paper) with input from an interdisciplinary advisory team. As described above, the nature of the research questions under investigation called for an interpretive research approach. As a result, the primary author experienced a transition from traditional engineering research into interpretive, or social, research in an engineering setting. We propose that such a transition is typical of many researchers in the emerging field of engineering education and thus provides a useful starting point for discussions of rigour in interpretive research.

In feminist psychology literature, Wilkinson (1988) conceptualises such a transition as the development of a 'sub-discipline' (e.g. interpretive research in engineering education) originating from a 'dominant paradigm' (e.g. traditional engineering research). Wilkinson (1988) proposes that the development of the sub-discipline can be facilitated by 'disciplinary reflexivity'; that is, a critical stance towards implicit assumptions associated with the dominant, or, parent, paradigm. It is for this reason that we have chosen to place 'ontological and epistemological assumptions' as the first tier in our model of reflexivity (see **Figure 2).**
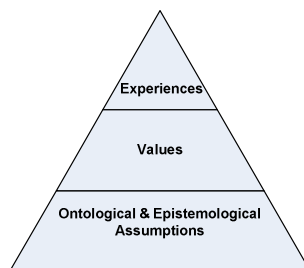

Figure 2: Three-tiered model of reflexivity

Following an appreciation of the fundamental ontological and epistemological differences between interpretive and traditional engineering research, the upper tiers of the model aim at increasing awareness of factors which influence researchers' subjective understandings of the research project. Most versions of reflexivity involve an examination of researcher preconceptions and motivations pertaining to the research question(s) (Gough, 2003). The upper two tiers of our model address the impact that researchers' values and experiences may have on the research process and findings. We

have chosen to focus on researchers' values and experiences for two reasons. First, these two areas of critical self-reflection emerged as most relevant to the study upon which this model is based. And second, we have prioritised a relatively simple model, with the view to demonstrating and thus encouraging reflexive practices, over a longwinded list of possible candidates for self-critical. It is therefore the researcher's own responsibility to decide which aspects of their research project could most benefit from reflexive practices. Some additional suggestions provided by Maso (2003) are: the researcher's intuitions, commitments, presuppositions, prejudices, and personal agendas.

It is important to point out at this stage that the purpose of reflexive practices is not to reduce the 'subjectivity' of interpretive research. Or, in other words, the purpose is not to give the impression that interpretive research is 'objective'. Rather, the purpose of engaging in reflexive practices is to recognise that subjective understandings are a critical part of interpretive research and then to harness those understandings with the view to increasing the rigour of the research process and findings.

In the sections that follow, each tier of the model is introduced with an abstract description, an illustrative example that draws on the abovementioned study and a discussion of appropriate strategies to incorporate reflexivity into the research process. The use of the first person in these sections refers to the primary author of this paper who collected data for the EPR project.

Tier 1: Ontological and epistemological assumptions

The first tier concerns the researcher's fundamental assumptions about reality (ontology) and ways of justifying knowledge claims (epistemology). For the researcher from a traditional engineering background, this concerns the tensions between an external reality that is 'out there' to be neutrally observed and a socially constructed reality that influences and is influenced by the researcher. Traditional engineering research is based on the former, 'dualisitic' (the researcher as *separate* from the research object) view of reality; while interpretive research typically follows a 'non-dualistic' ontology. In the latter view, 'fluid definitions of a situation are created by human interactions' (Neuman, 2006) and reality is, as such, socially constructed. This means that the researcher participates in these human interactions in the data gathering process and then constructs meanings from the data through interpretive analysis.

Example: As part of my work in the UK, I surveyed local residents' acceptance of and responses to recently installed household water meters. As part of this survey, I asked whether they performed specific water saving behaviours which had been advertised in an information pack provided by the local water company to residents upon meter installation, e.g. taking a shower instead of a bath, turning the tap of while brushing teeth etc. When interacting with the respondents, I had the impression that they felt more comfortable giving affirmative answers to my questions.[2] Upon reflection, I speculated that this could have been due to a number of reasons, for example a desire to be seen to be 'doing the right thing', or perhaps even because it was 'easier' to answer 'yes' to my questions in order to quickly complete the survey. It was thus unclear as to what extent their responses reflected actual behaviours. As a result, I felt uneasy reporting both the statistical and qualitative findings from my survey as I had to doubt the quality of the data.

Measure: This example demonstrates that it is the researcher's responsibility to be aware of non-dualistic elements of their research topic and methodology. By engaging in critical self-reflection both during and after undertaking the survey, I realised that I had implicitly assumed a dualistic methodology, i.e. 'yes' or 'no' answers to a list of water saving behaviours, whereas, in fact, I was trying to ascertain a non-dualistic reality, i.e. residents' acceptance of and responses to household water meters. Or, in other words, in constructing my survey, I had unconsciously assumed that I could neutrally observe an external reality, or 'truth', relating to how the installation of water meters had changed user behaviours. Critical self-reflection on the impact of the 'context of the asking' revealed the non-dualistic nature of my research and was thus a critical first step in ensuring a rigorous process. The upper tiers of the model aim at harnessing this critical awareness by examining factors which influence the researchers' subjective understandings of the research project.

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[2] This 'immediate impression' is an example of 'reflexive' awareness.

Tier 2: Influence of personal values

A central aspect that follows from the realisation of a non-dualist ontology concerns the potential influence of personal values on an interpretive research project. In this context, two positions are put forward in the literature. The first contends that values can 'intrude, or materialise' at various points in the research process that range from the choice of research area and questions, to the analysis and interpretation of data. To mitigate this, authors typically advise that the researcher provide the reader with an honest account of their preconceptions and bias' in so-called 'confessionary tales' (Bryman, 2001). In contrast, the second position holds that reflexive practices transform subjective elements of interpretive research from problem to opportunity (Findlay and Gough, 2003). For example Findlay (2003) highlights that critical introspection (for example of values) can yield insights which then form the basis of a more generalised understanding and interpretation. In the example below, we illustrate how a personal value biased aspects of the data collection in the present research project. We then show how reflexive practices can be used to reduce the likelihood of values intruding on the research process thus increasing the trustworthiness of research findings.

Example: In exploring how people's attitudes and water related behaviours have changed since the Millennium Drought in south east Queensland, a local resident referred to a dam project that was cancelled in 1989 stating that, if it had been built, 'we would have had plenty of water'. Listening to the audio recording of this interview, I realised that the value I place on leaving nature undisturbed prevented me from further exploring the resident's pro-dams views in the data gathering situation. Such a discussion may have revealed further insights relating to why the resident had not taken advantage of the government's rainwater tank incentive scheme, e.g. the resident possibly felt that the government had not done all it could to provide sufficient water to the area and did thus not feel compelled to step in and install a rainwater tank. This speculative exercise demonstrates how my values impacted on my ability to explore a potentially important aspect of the research question.

Measure: In the literature, reflective documentation is commonly seen as the most effective way of separating out preconceptions, such as values, (Denscombe, 1998; Richards, 2005). To mitigate adverse impacts such as that described above, I wrote a reflective memo to articulate my personal values relating to the topic of urban water supply. I then used this memo to generate an alternative value set. For example, I countered my value of leaving nature undisturbed with the value that 'man-made solutions in nature have greatly improved the quality-of-life of modern society' (Sochacka, 2008). This process is proposed in the literature to alert the researcher to potential risks of skewing data collection and analysis in the direction of their own biases and increase the researcher's awareness of a wider range of viewpoints which they are likely to encounter in the project (Richards, 2005). In this way, the reflexive practice of writing a memo provides an opportunity for the researcher to increase the quality of the research beyond simply a reflection of their own values. Similarly, sharing some of the content of the memo in the dissemination of the findings increases their trustworthiness as it gives the reader the opportunity to make their own judgments relating to the quality of the research (Bryman, 2001).

Tier 3: Influence of prior experiences

Prior experiences, like values, also have the potential to impact upon the research process. This is because interpretive analysis is based on the consideration of experiences of the research participants. The researcher's own range of experiences therefore play a crucial role in the process of generating knowledge within interpretive research projects.

Example: As an Environmental Engineer with professional experience in water management, I am familiar with the technologies and science associated with water treatment. Thus in early interviews, I found it difficult to relate to and understand some residents' emotional responses to the issue of water recycling.

Measure: To increase my awareness of such responses, I wrote a reflective memo about my experiences of water management which I then used as a basis to generate alternative experiences derived from document analysis of media articles, government reports and other sources. This process provided me with a broader knowledge base from which to conduct interviews and also served as a repository to explain and triangulate the data.

Discussion

In this paper we presented a three-tiered model of reflexive practice for engineering education research. The following paragraphs discuss (i) the characteristics of the model and how it is situated within the current understandings in the fields of engineering education as well as the social sciences, (ii) the use of the model in engineering education research and (iii) its appropriateness and potential for the emerging discipline.

(i) The model represents a systematic framework to approach the issue of reflexive research practice as a core aspect of achieving trustworthiness in interpretive research approaches. The fundamental considerations presented here draw on literature from the social sciences but the model is developed in the context of a concrete EPR research project in the field of engineering education. The model emerged from a personal journey of an engineering education researcher from traditional engineering to interpretive understandings of research that is representative of current developments across the field. In this context, the discussion of reflexive practice in interpretive research is relatively new to the discipline of engineering education that is currently in the process of adopting such research approaches (Borrego, 2009). At the same time, the topic of reflexivity and quality of interpretive research presents a challenge and opportunity as it is still controversially debated in those fields that more commonly adopt interpretive research approaches (Findlay and Gough, 2003).

(ii) In the context of engineering education research, we approached the question of reflexivity through a model that was presented in graphical form. Yet, the model is neither intended to be comprehensive in covering all aspects of reflexive research, nor is it prescriptive in its application to research practice. The simplified representation was chosen to make the fundamental aspects of reflexivity more easily accessible but its application necessitates caution and reflexive awareness. We pointed out other strategies and aspects of reflexivity that need to be determined specific to the context of a particular research project. In this sense, the model is intended to open and aid but not restrict understandings of reflexivity. With a view to the development of the discipline of engineering education research, the paper provides a theoretical foundation combined with tangible research experiences as a starting point for the community to discuss appropriate strategies and also to fundamentally examine some of the assumptions underlying engineering education research in a collective reflexive journey.

(iii) Such an endeavour offers a number of opportunities on several levels. A fundamental discussion of reflexivity in the context of engineering education research could move towards a discipline-specific understanding of this approach to promoting research quality and of the particular strategies employed in individual research practice. An example of the discipline-specific nature of the model presented here is the focus on the ontological and epistemological assumptions that are acutely relevant in the current development of the field. This transition of engineering education research to include interpretive understandings also offers opportunities for contributions to the discussion of interpretive research across the disciplines. From our unique transitional perspective, some aspects might emerge with greater clarity for engineering education researchers compared to members of fields that are more implicitly familiar with the assumptions underpinning interpretive research. As an example, the discussion of the presentation of reflexive practice through a model points to potential contributions of the engineering perspective. The graphical representation as a form of communication that is typical to engineering can provide clarity and easy access to the topic and can be carefully combined with the more fluid understandings that are characteristic within the social sciences. In similar ways, a discussion of discipline-specific understandings of interpretive research methods can not only draw on but also complement the knowledge from disciplines that traditionally employ these approaches.

Conclusion and further work

The model presented above provides a first step towards systemising strategies to incorporate reflexivity into interpretive research projects undertaken within the discipline of engineering education. It offers a road map to support the individual development of researchers embarking on interpretive approaches as well as a structured way to establish and demonstrate rigour. The next steps in this research involve the further development of specific strategies to increase rigour at various stages of the research process.

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