Communicating your findings in engineering education: the value of making your theoretical perspective explicit

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The authors observe that many research papers in engineering education do not explicitly state the theoretical perspective underpinning their work. In this article they argue for the value of theory in assisting researcher in communicating their research findings. Three theoretical perspectives that can be used to support one's research are described, namely; positivism, constructivism and critical inquiry, and in each case examples of research questions that best match the particular framework are given. Researchers are advised to be aware of the limitations of each perspective and to use the one that best assists them in understanding and solving the problems they wish to address.

Keywords: theoretical perspective; engineering education research; positivism; constructivism; critical inquiry

1. Introduction

Our experience of reviewing submissions to engineering education conferences and journals over several years, together with our own experiences of learning to do educational research in an engineering context has highlighted the difficulties that many authors, including ourselves, have in articulating the theoretical perspectives that inform our research. In this paper we use the term "theoretical perspective" to include both the philosophical justification for one's research design (methodology) and the basis on which the knowledge claims are made (epistemology).

Many authors do not make any explicit reference in their papers to a broader theoretical perspective, and this contrasts strongly with educational research in other disciplines such as literacy studies and science education. The challenge facing the engineering education community is to use theory effectively to help solve the problems encountered in our educational contexts and to build a common language among researchers. This is necessary if we wish to develop as a community able to engage with and build on each other's work, and to produce a deeper and more productive understanding of our educational contexts and our roles as researchers and teachers.

This will also allow us to draw more fruitfully on similar educational work from other disciplines in higher education.

We would argue that even if one does not articulate a theoretical perspective, there are always implicit assumptions behind the manner in which one conducts and reports on one's educational practice and research. Too many projects are described as if they had been conceived in a vacuum. Identifying and articulating a theoretical perspective is an important stage not only in supporting the knowledge claims in one's research findings but in effectively communicating these claims to the reader.

2. Why bother with theory?

Writing a paper is an exercise in communicating with colleagues interested in one's field. The different objectives that writers have can be categorized as follows:

(i) Describe innovative educational practice, possibly including an evaluation of its success.
(ii) Propose a new way of doing something.
(iii) Suggest a new way of thinking about something.
(iv) Report the findings of educational research.

These objectives are not mutually exclusive, and two or more are frequently combined in one paper.

Readers also come to a paper with a range of interests and objectives, which can include the following:

(a) To understand what the author's purpose is in writing the paper.
(b) To understand what the author is describing or analysing.
(c) To decide the relevance of the author's work to their own context.
(d) To be able to judge the claims that the author is making.
(e) To be directed to work of a similar nature in the literature and establish how the author's work compares with this.
(f) To incorporate new ways of thinking about education into their personal viewpoints and approaches.

Usually most of the papers give the reader sufficient information to satisfy objectives (a)–(c). What does one need to provide in order for the reader to achieve the other objectives?

Consider objective (d). When reading a paper, what would one make of a claim such as: "Students' learning of topic X was vastly improved by the use of teaching technique Y". To assess this claim, one needs first to understand what the author means by the term "learning". Does this refer to the memorization and recall of facts, the understanding of concepts, the interpretation of new information, or something else? Furthermore, on what basis was learning assumed to have improved? Maybe test scores improved, but the reader might wonder whether the tests used were comparable, or whether students were coached for the final test. Maybe the class had only 12 students, and the reader might speculate whether a larger sample would have produced a different result. On what basis do we claim that our work should be taken seriously?

With regard to objective (e), in literature reviews authors might refer to work in similar contexts, and these might have similar or contradictory findings to their own. How do we interpret this? Does this invalidate or support the work in question? Can one compare findings in this way? How similar do the contexts have to be? Does one need to use the same questionnaire or test? What is the purpose of a literature review?

Finally, consider objective (f). On the one hand, one comes across a new idea which many people are using and which sounds good. How does one decide whether it will be appropriate to adopt in one's context? On the other hand, one finds generalizations that have a commonsense feel to them but are not substantiated. For example we often read statements such as: "Today's students do not work as hard as the previous generation", "Staff are more interested in their research than their teaching" or "Students are doing engineering for the wrong reasons". How does one judge the validity of such statements? As a community of engineering educators, how do we develop a common language for talking about these issues and clear ways of deciding whether or not to adopt an idea or viewpoint?

Addressing the above points takes one into an area "behind the findings" where the theory lies and it becomes necessary to set out one's theoretical perspective. How does one start bringing theory into one's work? Fortunately many people have done much thinking and writing in this area and one does not have to start from scratch. There are a range of resources that one can consult; in education research a widely used text is that of Cohen et al. (2000).

In this study, we focus on three major theoretical perspectives that are frequently referred to in the literature on how to do educational research: positivism, constructivism, and critical inquiry (Lincoln and Guba, 1985; Carr and Kemmis, 1986; Crotty, 1998). We are not claiming that there are no other useful theoretical perspectives, but these three are frequently referred to in the education literature. Crotty (1998) suggests that the major distinction is between positivism and perspectives that are not positivist, including constructivism and critical inquiry, which we focus on here, as well as postmodernism.

3. Theoretical perspectives

In this section, we present a brief description of each of these three perspectives, summarized in Table 1, and comment on their relevance to engineering education research.

3.1. Positivism: is the scientific method always appropriate?

Many of us working in engineering education have our academic origins in science or engineering where the traditional way of conducting research involves the use of the "scientific method". According to this method, testable hypotheses need to be generated, and these are either confirmed or refuted by means of objective investigations. This involves the researcher adopting a position as a neutral and objective observer. This theoretical perspective is commonly referred to as positivism.

This perspective emphasizes the importance of measurement. Research using this perspective aims to understand only those phenomena that can be objectively measured with the goal of establishing facts and laws that can be used to predict future situations. It can be debated whether the classical scientific method as put forward by Francis Bacon is always appropriate within technical research in science and engineering, and "post-positivism" that incorporates elements of uncertainty and falsifiability goes some way towards addressing these challenges (Crotty, 1998).

Table 1. Comparison of three theoretical frameworks.

	Positivism	Constructivism	Critical Inquiry
Aim of research	Establish facts and laws	Develop useful interpretations	Achieve social change
Research is guided by	Testable hypotheses	Research questions	Social problems
Role of researcher	Objective observer	Constructer of interpretations	Change agent

In this article, we would like to focus on whether the positivist perspective, and its post-positivist offshoot, has a place in engineering education research.

Consider, for example, the research into understanding student performance in engineering. A testable hypothesis would be "Achievement in school-level mathematics is a better predictor of performance in first year university engineering courses than achievement in school-level science". The method would involve applying appropriate statistical procedures to a data set from the target population and analysing correlations that emerge. To ensure that one's result was not dependent on a particular year's intake, one might repeat the study over several years and thereby attempt to predict future student performance. Research using this perspective often aims to identify "factors" which influence an outcome, for example the study by Tynjälä et al. (2005), which seeks to identify factors related to study success in engineering education.

What are the limitations of this approach? Underpinning positivism is an assumption that problems can be researched in ways that reveal objective facts and causal relationships, independent of the researcher. The first limitation while using this approach is that in many cases the need to develop a testable hypothesis can force a narrow focus on a particular issue before a problem has been fully explored.

A more severe limitation of a positivist approach is that of all the possible research questions that one might wish to ask in an engineering education project, only a small subset lends itself to formulation in hypotheses. For example, in the area of researching students' performance, investigations of the nature of student experience during the first year of university do not easily lend themselves to prior generation of many meaningful hypotheses. Positivism assumes that a set of measurable factors that are the primary cause of students' success or failure can be established. Anyone who has worked closely with students will appreciate that a host of complex and interrelated factors affect student success. We would argue that a positivist perspective, while useful for addressing particular questions, if used exclusively, will constrain the scope of possible research findings. We turn therefore to the consideration of two other perspectives.

3.2. Constructivism: developing new understandings of our contexts

Constructivism focuses on the way individuals, both researchers and participants, make sense of their experiences. Within this perspective one assumes that participants experience the world around them in different ways. The aim of the research is therefore to develop useful interpretations of these experiences rather than to uncover "the truth" or "facts". Useful interpretations are those which describe a "recognisable reality" (Parlett and Hamilton, 1977), provide new and helpful understandings of a context, and point to ways of addressing a problem.

Consider again the research into students' performance in first year engineering. A constructivist perspective would focus on how students experience the range of elements that make up first year, including tests and exams, lectures, interactions with peers, staff, and the institution. As a researcher one could not assume that one's interpretation of the situation matches that of the students, nor could one assume that all students have the same experience. Some examples of this kind of research are Carew and Mitchell's (2002) study into engineering students' understanding of sustainability and Donald's (1992) research into lecturers' and students' conceptualizations of learning tasks in engineering courses.

When working in the constructivist perspective, instead of an hypothesis, the researcher is usually guided by a set of research questions, which are formulated based on the perceived nature of the problem and prior research. For example, when considering examinations, one could formulate a question such as: "What are the different ways in which students experienced a particular question in the Mechanical Engineering examination?" Alternatively, in the area of conceptual understanding, one might ask: "How does prior learning influence conceptual

development in first year Chemistry?" or, in probing the impact of social experiences: "How do friendship groups influence student learning behaviour?" For a researcher who has recently implemented a tutorial programme, an appropriate research question might be: "How do students use lectures and tutorials in their learning?"

In the science and engineering education literature, the term "constructivist" appears frequently, sometimes in the sense referred to above (as a theoretical perspective) but possibly more often with reference to a particular view on learning. Constructivist learning theory is based on the assumption that learners actively construct knowledge and that knowledge cannot be passively transmitted from the mind of an expert into that of a novice (Moll, 2002). This has been a powerful learning theory particularly in science education, and many researchers have used it to explore students' conceptual frameworks without necessarily making this explicit. However, adopting a constructivist theory of learning is distinctly different from adopting a constructivist theoretical perspective in research. It is possible to hold a constructivist theory of learning while conducting research from a positivist perspective (Nola, 1998).

3.3. Critical inquiry: dealing with issues of power and inequality

Research conducted in the above two perspectives may bring to light issues of race, gender, and other aspects of diversity. A third perspective, which is another way of approaching these issues, assumes that power relations lie at the heart of everything that happens in society. Research in this perspective, referred to generally as critical inquiry, is driven by a desire to change the way society works in support of groups identified as marginalized and disempowered, with the researcher playing an active role as change agent (Carr and Kemmis, 1986).

Consider again the example of research into students' performance in first-year engineering. Research from a critical inquiry perspective would focus on revealing how the inequalities in society influence student performance. Possible research questions in this framework include "Does the institutional culture result in different groups of students feeling at home or alienated?", "How does being labelled an 'underprepared student' impact on one's learning?", "Are there elements of the disciplinary culture of engineering that affect the performance of female students?"

Research questions such as these that focus on people's experiences could also be addressed with a constructivist perspective. However, using critical theory leads to different research findings. If one's aim is to improve society through one's research, then critical inquiry is more likely to produce findings that highlight productive routes for action. In engineering education, critical theory provides a valuable approach for exploring the experience of female students (Stonyer, 2001).

4. Conclusion

At this point, you might be wondering which is the "right" theoretical perspective to be used in engineering education. There is clearly a difference of opinion on this score. Many researchers with a background in the natural sciences assume that the positivist scientific method is the only way to do research. We argue that positivist research can offer an appropriate framework for certain research questions; however, we feel that it is of limited value in addressing the complex problems that are evident in educational contexts. In our view, the constructivist perspective is helpful in illuminating contexts involving individual learners, while the critical inquiry perspective has greater explanatory potential for addressing more complex problems at a broader social level. In the end researchers need to choose a framework that most successfully helps them to understand and solve the problems that they feel need to be addressed in their contexts.

Locating a theoretical framework that matches your intentions and is appropriate for your research problem can help you communicate the assumptions underlying your research, the methods you have chosen, and how you want your findings to be interpreted. This will help other researchers to engage with what you have written and assist in building a community of engineering education researchers with a common language and an understanding and respect for the different approaches that exist in educational research.

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