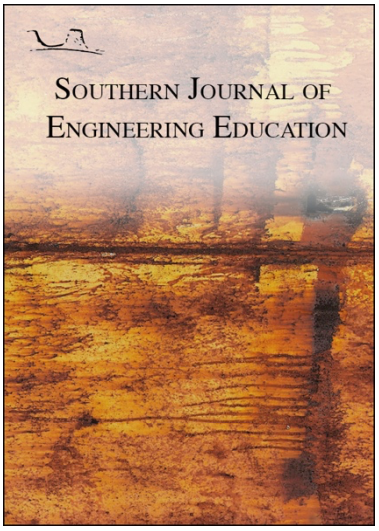

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Evaluating and publishing curriculum development activities

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Evaluating and publishing curriculum development activities

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This article is a reflection on the evaluation of curriculum development activities, drawing on the experience of having led a major cross-departmental curriculum reform, as well as having reviewed a significant number of manuscripts as the editor-in-chief of an engineering education journal. It aims to highlight some of the potential pitfalls in the design of curriculum development evaluations, especially when the intention is that such evaluations should be presented for publication.

Keywords: engineering education research, research approaches, theoretical frameworks, publishing

Introduction

Most conscientious teachers include evaluation as part of their teaching practice, typically to gain a greater understanding of the effectiveness of a particular approach they have adopted. However, increasingly there is a desire to go beyond evaluation as a self-reflective practice and look to disseminate, with supporting evidence, the outcome of innovations in teaching practice or curriculum development. In most practical terms, there is a continuum between the more routine evaluation of teaching practice through to rigorous educational research. The framing of Boyer (1990) is often used, which, as he comments, might be thought of as having four separate yet overlapping functions. For the sake of this paper, I am mostly concerned with two of these four areas, the scholarship of teaching and the scholarship of application.

Research in engineering education has a long history, with journals such as the *Journal of Engineering* produced by the American Society for Engineering Education (ASEE) and the *IRE Transactions on Education* (now *IEEE Transactions on Education)*, launched in 1925 and 1958 respectively. For much of this period Engineering Education Research (EER) covered a broad range of scholarly activities. The late 1990s saw the first signs of a division forming (Streveler, Borrego, and Smith, 2007) between the practitioner-researcher and those who specialised solely in engineering education research. The scholarship of teaching (often

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extended to the scholarship of teaching and learning (SoTL) (Fanghanel et al., 2016), was developed drawing on the work of Boyer and has become more commonly recognised (and hopefully rewarded (Graham, 2016) as a critical characteristic of professional teachers in higher education. The early 2000s saw the first dedicated schools/departments of engineering education formed (Benson et al., 2010) and the relaunch of the ASEE *Journal of Engineering Education* as 'an archival journal of scholarly research in engineering education' (Felder, Sheppard & Smith, 2005, p. 8).

In truth, although the number of dedicated researchers in the field of EER has grown tremendously (Wankat, Williams & Neto, 2014; Borrego and Bernhard, 2011), the vast majority of research in the area is undertaken by practitioner-researchers as a form of active research in their own classrooms (Wint & Nyamapfene, 2021). Such researchers are actively engaged in the curriculum developments and innovations being researched. In most cases this work will fall as much into the scholarship of application as it does into the scholarship of teaching, applying the helpful specialisation of Boyer's area to engineering provided by Froyd (2013). The aim of these researchers is not just to undertake evaluation as an internal quality assurance function, but a distinct interrogation of how prior research in learning and teaching is applied to design and deliver instructional strategies. Typically, the primary question will be whether the applied technique has improved the learning outcomes for the students involved.

Although sharing many features with educational research founded in the social science traditions, there are some distinguishing features that must be acknowledged. As much as we would like to compartmentalise the researcher and the practitioner, this is not always completely possible. This is especially true for large scale curriculum reform where pressures of delivery inevitably compete with the needs of the pedagogic research programme.

Advice and considerations when undertaking a study

In the following sections, I review some of the considerations that practitioner-researchers may wish to consider as they shift from evaluation of their own practice to developing research for publication. These observations come from both sides of the divide, being a practitioner-researcher myself, and having supported other practitioner-researchers to make this transition as part of a faculty-wide curriculum development programme, but also as the editor-in-chief of an engineering education journal, where well over 1000 manuscripts crossed my desk.

1. Be clear on the approach and outcomes

For many engineering educational researchers who are also practitioners, the central research questions of their studies will emerge somewhat organically through their experience with their students. In many cases it will be from a desire to understand the effectiveness of an educational intervention or technique that they feel is novel in their specific context. These will fall into in the scholarship of application or the scholarship of teaching domains (Boyer, 1990), drawing on existing education research and applying it to the design of a specific educational activity. Others may wish to understand more about the nature of their students, perhaps uncovering details of their motivation for their approach to study or their choice of discipline. These would fall into the scholarship of discovery. All these areas lead to quite specific research question/s and it is essential to any paper that these be clearly articulated at the outset. As outlined by Savin-Baden & Major (2013, p. 99), 'Being able to articulate an investigable question that captures the topic, and the purpose of the research is critical to the research endeavour'. Experience has shown that the lack of a clearly articulated research question is one of the most common criticisms raised by reviewers, as it is not only a problem in itself, but also leads to uncertainly and confusion with regards to many other aspects of the paper.

2. Design an evaluation around the change

As introduced above, the aim of most studies in this area is to show that the instructional strategy being implemented is an effective approach to help students achieve a specified set of learning outcomes. It may be that the topic is viewed as difficult and therefore typically receives low grades, or it may just be that some higher cognitive aspects (for example, synthesis skills) are felt to be lacking in traditional approaches. Regardless of the explicit reason for the change, to construct a persuasive narrative for a study, evidence not only to support the nature of the innovation, but also of its effectiveness, is needed. Ideally the reason for the intervention proposed can be demonstrated through rigorous design of the process with reference to relevant pedagogic literature.

It will also be necessary to provide an evaluation of the implementation of the instructional strategy. This is an area I will explore in more detail in the rest of the paper. To conduct a rigorous evaluation there are a few elements that are typically necessary. Firstly, some context for the situation is needed before the intervention is applied. Secondly, the approach to collecting evidence for impact will need to be linked to a theoretical framework, and most

importantly, a methodology for collected data will need to be determined. It is still surprising to me how many papers submitted (and some published) do not explicitly state these steps, although they form the cornerstone of producing educational research that can be understood and adopted in different contexts.

It is probably worth taking a moment to consider the implications of a rigorous data collection methodology. Whilst the variety of data collection methods is extensive, and it is in no way possible here to produce an exhaustive list, there are some fundamental questions that a researcher should consider when choosing a technique. For a study that is considering a student learning intervention, the central question will be: 'How well have students learnt a given aspect of the curriculum?' While there are several approaches to collecting evidence of students achieving learning outcomes, student self-report data, while important, may not by be sufficient to support assertions of effectiveness. At best this provides a measure of the students' perception of learning, although some research has shown that this is often biased (Deslauriers et al., 2019).

An alternative approach often considered is that of students' grades. While this is often considered a more objective measure of student performance than a self-report survey data, it must be recognised that it is primarily an assessment tool, not a research tool. While if used carefully it can provide useful information, appropriate design to ensure that it serves the dual purpose must be considered, where issues of reproducibility across cohorts must be considered. Researchers keen to understand the impact of particular aspects of their intervention might want to consider pre-/post-tests, control groups (although not always appropriate), interviews/focus groups with either students or staff, observations, or the longitudinal studies that track students though a number of educational experiences.

3. Ensure that the baseline is recorded

As observed above, to enable a researcher to provide evidence that a change in approach or pedagogy has had an impact, some measure of the state of the system before the innovation is applied is necessary. While perhaps obvious, this can be surprisingly difficult when external forces are driving the pace of change, as is too often the case. However, both from a researcher's point of view, as well as from a change management perspective, the ability to provide a clear picture of the prior state is important. As pointed out by Ruth Graham (2012), a reminder of the underlying reason for the change can be vital to its long-term sustainability.

Inevitably, capturing the prior condition will require a mix of quantitative and qualitative measures that feed off the desired outcomes discussed in the previous section.

4. Choose and describe an appropriate theoretic framework

A theoretical framework consists of concepts which, when situated in the relevant scholarly literature, demonstrate an existing theory that can be used to support the research study. It will generally use known and accepted theories and concepts to underpin the research work. The theoretical framework (sometimes referred to as the philosophical perspective) is not always explicitly acknowledged in a publication, although an explicit statement of the theoretical assumptions as well as the researcher's philosophic stance can assist the reader or reviewer to critically evaluate the work. Researchers use this framework as a basis for their hypotheses as well as a tool to enable generalisation from the description of a phenomenon to a broader prediction, as well as identifying the limits of these generalisations or conclusions. In some cases it may also guide the choice of research methods and methodologies by identifying the key variables that will influence outcomes. One set of frameworks of particular interest that has been increasingly applied in engineering education in recent years could be categorised as critical or critical social theoretical frameworks. These frameworks take the approach of interrogating and critiquing existing power and social structures with aim of addressing inequalities and making a positive impact on the experiences of those who have been oppressed by these structures (Mejia et al., 2018).

5. Choose a methodology

The typical distinction and debate when discussing the methodologies to be adopted for a given study revolved around the distinction between quantitative and qualitative methodologies. Although it is often felt that researchers with backgrounds in engineering and sciences gravitate towards quantitative methods, both methods can be equally rigorous and valid. The choice should be driven by the needs of the research question, with mixed approaches that combine both quantitative and qualitative elements having become commonplace in EER. In this section I highlight some examples of qualitative methodologies that are commonly used in EER. For an excellent and more detailed examination of their use in EER and further examples, I would recommend the work of Borrego, Douglas & Amelink (2009) and Case & Light (2011).

Case study: Perhaps the most common approach adopted by engineering education researchers is the case study (Creswell, 1998), aligning as it does with an emphasis on the scholarship of application domain. Case studies are thus often the result of the application of specific, research-informed teaching and learning approaches to a researcher's own practice. In a case study, the researcher provides an in-depth analysis of a single, distinct instance of the phenomenon under investigation. Although not exclusively so, case studies will typically make use of qualitative data gathered through a variety of methods. It is of course important to acknowledge in any case study the scope of the results obtained. A researcher can either implicitly or sometimes explicitly assumes that such results are generalisable. This fails to acknowledge the heavily context-dependent nature of any case study, which will often be exposed as part of a good study.

Case studies can focus on a single class or discipline but may also extend to a geographic region or administrative area. For example, the investigation by Joy Gwynne-Evans, Chetty & Junaid (2021) of how ethics is integrated into engineering education takes South Africa as a case study to consider how policy formulation and specifically programme accreditation can play a role in driving curriculum change. This then allows them to describe how their conceptual framework might be applied to integrate ethics teaching more comprehensively within engineering programmes.

Grounded theory: The central tenet of grounded theory is that theory can be generated from the data that is gathered within the study, in contrast to approaches where an existing theory is used as the starting point of the study. It has progressed over time from its first formalisations (Glaser & Strauss, 1967) with a number of variants emerging. A common approach to such a study is to gather a set of data; this may consist of narratives either collected via interviews or taken from reports or reflective pieces of writing, or may take other forms such as visual media or observations. The researcher then proceeds to code this data with the aim of grouping similar data elements into distinct sets. Efficient and effective coding undoubtedly takes skill and practice, and as an inherently iterative process, it can be time-consuming. A number of different coding strategies exist: open coding, where the researcher looks to identify meanings or feelings and creates new codes and sub-codes as necessary; axial coding, which identifies related codes; and selective coding, which explores the relationship between a core code and other codes. As the researcher works through the data set, connections between elements emerge and core concepts develop. Here 'memoing' or annotation of ideas and reflections

while coding the data is common practice to ensure that observations are captured to feed into later analysis. The process of coding, categorisation of codes and constant comparison – whereby categories are compared until no more variation occurs – repeats until a state referred to as 'saturation' emerges where no new insights emerge or codes/categories are needed, even if new data is added. The final stage is then theory generation, whereby the insights from the data coding process and the aggregated observations collected through memoing are used to develop a theory to explain the phenomena under study.

As an example, Roach et al. (2017) used inductive grounded theory in their study to analyse the peer-assessment rubrics generated by students as part of a project-based course. Through an iterative coding process, a reduced set of categories was produced. They were then mapped to the framework of the affective domain as set out by Krathwohl, Bloom & Masia (1964).

Pragmatic qualitative approach: While the approaches discussed so far are often used, it is increasingly common for researchers, and in particular those in professional fields such as education, to find themselves using a varied/diverse set of methods as a practical approach to answering a research question. Although perhaps not as commonly used as more established methods such as ethnography or grounded theory, pragmatic qualitative research methods draw on a diverse set of methods, that most importantly offer a descriptive account from an interpretive perspective to understand a phenomena or event. By definition, relying on an eclectic set of approaches makes it hard to specify any standard techniques applied. However, it must be noted that although this may give the impression that such an approach is not rigorous, it is of even greater importance when not adopting a recognised research approach that pragmatic qualitative research studies fully describe their research methodology and ensure that the data collection and analysis techniques are rigorous. Some have taken this approach further, integrating both quantitative and qualitative methods. For example, Shekhar et al. (2018) investigated student resistance to active learning by combining student focus groups, classroom observations and instructor interviews with quantitative survey instruments.

Narrative approaches: Central to the conceptualisation of narrative approaches is that the human story can be used to generate meaning and give insight into the events experienced. As with some of the other approaches discussed here, there is not always a clearly defined boundary between this approach and others. However, there are some key features that are typical of narrative approaches. The main one is that the process of telling a story and the

resulting story itself are the main focus of the research study. With that in mind, it is not unsurprising that most studies will concentrate on a single or small group of participants potentially following them over a period of time. Some flexibility in data collection is needed to ensure that participants can tell their own stories in ways that work for them, although some also argue that a central tenet of narrative approaches is that they are a literary form and as such, the participants' construction of the story in written form is of utmost importance (Creswell, 2007). Regardless of the medium, however, it is central to this approach that narratives rich in social and cultural context are produced which are authentic. In their analysis, care must be taken not to lose or dilute the voice of participant. It is inevitable as part of the process that some 'retelling' of the story will occur; however, the tendance to impose meaning that perhaps was not originally intended must be resisted.

An interesting example of this approach aimed to consider why women tend to leave the engineering profession (or engineering studies) at a higher rate than men. To investigate this (Seron et al., 2018) collected personal diary entries from 40 students across four institutions. This included both men and women who were asked to provide entries at least twice a month about their educational and career decisions throughout the course of their studies. In analysing the resulting narratives, it was found that while men and women had similar reasons for enrolling in engineering and both groups were equally successful in their studies academically, as the programmes progressed women doubted their problem-solving abilities more than men. They also reported experiencing gender stereotypical tropes while engaging in teamwork, reporting being relegated to the more secretarial roles within the teams while their male colleagues commanded the more technical positions.

6. Determine an appropriate data collection method

Once a methodological approach is determined, most studies will require the collection of data. In some instances, the approach will provide strong cues to the methods of data collection (for example narrative analysis) whereas in other cases a range of options will be available.

Perhaps the most common approach of those moving from the evaluation of their practice to engineering education research is the survey. This is unsurprising as the student evaluation survey or instrument with a similar title is ubiquitous across the higher education sector. While such a tool can provide valuable insight into the perceptions of students, its limitations and biases must be clearly recognised. Returning to the earlier point that a core aim of most studies

in the scholarship of application is to demonstrate that a particular approach is more effective in achieving a set of learning outcomes, the role that self-report data produced from a student survey might play in achieving this aim must be critiqued.

Firstly, in the majority of surveys students are being asked to both self-report (i.e., report on themselves) and administer the survey themselves. Depending on the nature and context of the survey, students may tailor their answering of the questions to give socially acceptable responses – which may result in either under- or over-reporting of particular aspects, depending on the prevailing social viewpoint. To be robust, it also requires all participants to share an interpretation of the question. In self-administered surveys this calls for good question design to ensure that a range of views can be captured. Another consideration is the inherent issue of sampling within the survey cohort. Low response rates may mean that the respondent group fails to adequately represent a sufficient diversity of population to provide valid results. While many argue that response rates can be improved by adopting certain approaches and careful survey design (Sax, Gilmartin & Bryant, 2003; Saleh & Bista, 2017), by the anonymous nature of most surveys as traditionally administered, it is often impossible to quantify the effect this may have.

Lastly, the inherent bias that such self-reporting brings must be acknowledged. There is a wealth of research that demonstrates significant biases in the responses of student cohorts on the basis of gender (Mitchell & Martin, 2018), ethnicity (Fanid et al., 2019; Chávez & Mitchell, 2020), and even the presence of cookies (Hessler et al., 2018). Considering these issues, it is not unexpected that while the use of self-report student surveys may have some uses, as a rigorous research tool to demonstrate the impact of an approach, they have limited value.

An interesting approach that can be very powerful but is relatively infrequently used in engineering education research is observation. This technique draws on the deeply held belief of qualitative researchers that true investigation must take place in natural environments and draws on ethnographic traditions of observing both context and action. Therefore, when working in this way, it is important to capture the context in which participants work as well as the detailed patterns of their activities and interaction. This is an ideal way to counter some of the biases described above where participants, for example in teamwork activities, report more or less favourably on their experience due to social norms that are actually witnessed to be the case. There are number of techniques which can be used to support observation, with

the most appropriate being determined by a careful consideration of at what level of involvement the research ought to be in relation to the activities being observed. In some cases, a researcher can be entirely peripheral and passive, observing from a distance, while some argue that this is unlikely to create enough richness and that some level of participation is necessary to make observation studies successful (Savin-Baden and Major 2013).

In Lahiff et al. (2019), an 'unobtrusive observer' model was followed to address the question of how learning takes place in disciplinary-based project-based learning activities. The team observed several groups during their facilitated team sessions and supplemented the observations with interviews and focus groups with both staff and students to allow some of the observed phenomena to be discussed in more detail.

The use of interviews is a more common approach which, as noted above, is often part of a mixed approach study. Interviews may range from *structured,* where a set script is used; through *semi-structured,* where there are set questions, but space is left to explore areas further as they arise; to *unstructured* approaches where an open, conversational style is adopted in line with an overall goal. While this may seem quite straightforward, there is a definite art to being a good interviewer. Managing to elicit rich answers without leading the interviewee, and while being a non-judgemental listener, takes some practice. In developing strong interview questions, the researcher should consider how to provide the interviewees with opportunities to share their experience in a way that will provide useful data for interpretation in the analysis phase of the study. This will typically mean avoiding questions that might result in yes/no answers, and instead using questions that will prompt the interviewee to describe their thoughts, feelings or specific activities in a way that will provide insight into their thought processes. Perhaps less obviously, it is often considered best to avoid direct 'Why?' questions, as these may lead the participant to theorise in a way that might not be helpful to the study (Cohen, Manion & Morrison, 2018).

There is a wealth of examples in EER using interviews. For example, Vandersteen, Hall & Baillie (2010) conducted 32 semi-structured research interviews with both engineers and non-engineers involved in engineering, international development, and community development projects to understand the relative merits of international and local community-based projects. The study adopted a phenomenographic research approach (an approach that seeks to uncover

the way humans experience a specific event) to determine the variation between individuals' perception and constructed meaning of the activity.

In a study by Smit (2010), semi-structured interviews with PhD supervisors were conducted to investigate the use of situated learning as a framework to describe the learning process within doctoral study. To supplement the interviews, surveys were undertaken with a group of students. In contrast, Collier-Reed, Case & Linder (2009) interviewed school pupils after they engaged in an engineering activity, again using a phenomenographic approach.

As can be seen from some of the above examples, it is exceptionally common that studies use more than one data collection method. These are typically termed multi-method studies (if from the same methodological tradition, e.g., qualitative research) or mixed-method research studies (if collecting and integrating qualitative and quantitative data).

7. Acknowledge the limitations

Another common criticism levelled by reviewers is that papers over-generalise or over-state their claims. It is important that engineering education researchers acknowledge that generalisation will be difficult, as the majority of the research that is developed by researcher/practitioners are case studies, and that limitations are a natural by-product of most 'action-research' of this nature, which is highly context-dependent. While some aspects may be generalisable to classes in other contexts, it is important that the limitations of a study are explicitly stated and that authors are clear about what the paper can and cannot explain. This is perhaps one of the most difficult transitions for an engineering researcher working in the social science domain. Whereas those trained in the sciences are used to universal and reproduceable results that can be expressed with a confidence akin to a statement of fact, this is very rarely the case with educational research.

Conclusions

The transition from engineering academic to engineering education researcher is not one that is straightforward, but one that is increasingly being encouraged as universities worldwide place further emphasis on the scholarship of teaching and learning. This paper has aimed to provide rudimentary advice and guidance to those embarking on such a journey. It encourages them to reflect on their experience and how social science research techniques might be applied

to their practice with the aim of moving from evaluative approaches to scholarly engineering education research publications.

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